Ground Robotics Capabilities Conference & Exhibition

"Into the Hands of the Warfighter"

3 – 6 March 2008

San Antonio, Texas

Agenda

<u>**Tuesday, 4 March 2008**</u>

Opening Remarks – Mr. David Ahern, Director, Portfolio Systems Acquisition, Acquisition, Technology and Logistics, OUSD

Keynote Speaker – GEN Paul Kern, USA (Ret)

OSD Ground Robotics Update – *Mrs. Ellen Purdy*, Director, Joint Ground Robotics Enterprise, Acquisition, Technology and Logistics, OUSD

Ground Robotics and the Joint Warfighter - CDR Peter A. Young

Reinhard

<u>**Wednesday, 5 March 2008**</u>

Keynote Speaker – Mr. Rodney Brooks, iRobot

Keynote Panel – International

- <u>Mr. </u>Nicholas S.J. Karvonides, Institute for Defense Analyses (IDA),Alexandria, VA
- <u>Mr. </u>Henrik I. Christensen, KUKA Chair of Robotics, Georgia Institute of Technology
-

<u>**Thursday, 6 March 2008**</u>

Keynote Speaker – Mr. Richard Rumpf, Former Acting Assistant Secretary of the Navy for Research, Engineering and Systems; Rumpf Associates International

Working group B – Small Business Issues
Working group C – Technology "Longpoles"
Working group D – Ground Robotics In Homeland Defense
Working Group F – Combat Support/Combat Service Support Issues
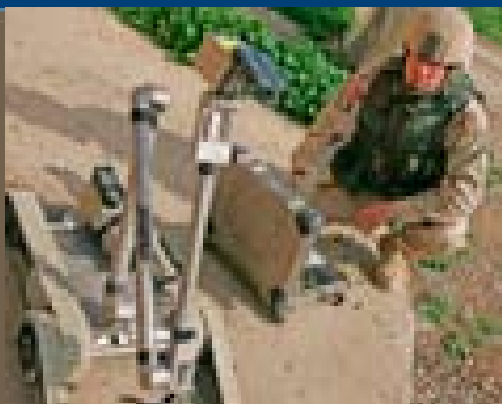*Working Group G* – Operational Issues/Challenges
Working Group H – Interoperability

CONFERENCE OBJECTIVE

The purpose of this conference is to bring together warfighters and homeland security users, technology developers (govern and acquisition professionals to address increased responsiveness to user's needs. This conference will also provide a forum fo ideas and methodologies to provide U.S. forces with unmanned ground technologies. The conference is intended to foster crea series of panels and speakers will present a wide array of thought provoking insights from diverse perspectives. Multiple focuse participants the opportunity to identify critical issues and needs, and develop practical steps for a path forward to resolve these

WHO SHOULD ATTEND?

OPERATIONAL

- Tactical Users
- Requirements Generators
- Concepts Developers
- Trainers
- Logisticians

TECHNOLOGY

- Government laboratories, Industry and Academia focused on unmanned ground systems.

- Developers of peripheral technologies (power, controllers, manipulators, tools, sensors, miniaturization, etc.).

ment, industry and academia),
or the exchange of information,
tive "out of the box" thinking. A
ed breakout sessions will afford
issues.

2008 GROUND ROBOTICS CAPABILITIES CONFERENCE & EXHIBITION

MARCH 3 - 6, 2008
GRAND HYATT SAN ANTONIO

Situated on the banks of the Riverwalk, the new Grand Hyatt San Antonio hotel presents contemporary style and an entirely new level of comfort, luxury and convenience among San Antonio hotels. The Grand Hyatt is adjacent to the San Antonio Convention Center and provides stunning views of downtown San Antonio and HemisFair Park.
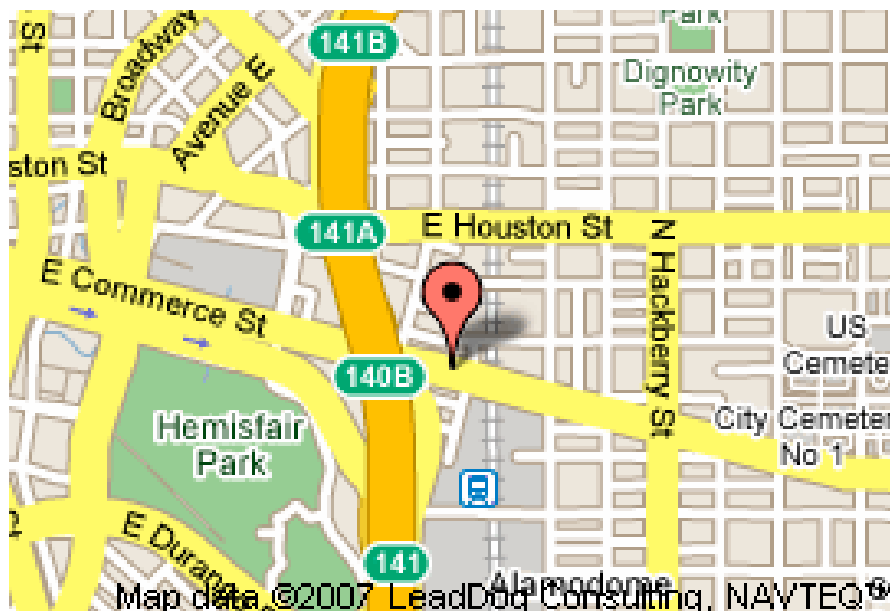
SAN ANTONIO, TX

OTHER LOCAL POINTS OF INTEREST

Henry B. Gonzalez Convention Center—Adjacent to the Grand Hyatt Hotel

River Walk (Paseo Del Rio)—Adjacent to the hotel

HemisFair Park—1 block from the hotel

IMAX Theater—1 block from the hotel

Shops at La Villita Arts Village—1 block from the hotel

River Center Mall—1 block from the hotel

The Alamo—3 blocks from the hotel

Market Square (El Mercado)—½ mile from the hotel

AT&T Center—2 miles from the hotel

San Antonio Zoo—4 miles from the hotel

Fiesta Texas—15 miles from the hotel

Sea World®—15 miles from the hotel

ABOUT NDIA

NDIA'S VISION

America's leading Defense Industry association promoting National Security

NDIA'S MISSION

ADVOCATE: Cutting-edge technology and superior weapons, equipment, training, and support for the War-Fighter and First Responder

PROMOTE: A vigorous, responsive, Government – Industry National Security Team

PROVIDE: A legal and ethical forum for exchange of information between Industry and Government on National Security issues

NDIA'S MOTTO

Strength through Industry and Technology

NDIA provides its members and customers broad outreach and sector coverage through its chapters, technical, policy, and war-fighting divisions, and the complimentary missions of its affiliate

DOD APPROVAL

The Department of Defense finds this event meets the minimum regulatory standards for attendance by DoD employees. This finding does not constitute a blanket approval or endorsement for attendance. Individual DoD Components commands or organizations are responsible for approving attendance of DoD employees based on mission requirements and DoD regulations.

WORKING GROUP DESCRIPTIONS

WORKING GROUP B:
SMALL BUSINESS ISSUES:

A continuing area of concern among small businesses is how to become involved in the DoD acquisition process. The focus of this break out session will be to identify the key issues faced by small, non-traditional businesses and develop courses of action for both industry and the government to overcome these issues.

WORKING GROUP C:
TECHNOLOGY "LONGPOLES":

The successful demonstration of first generation ground robots in defense and commercial applications has been witnessed by all. As these amazing vehicles are tasked to do more, this session will identify what the next level of robotic performance should be, especially in the areas of affordability, R&M, and manufacturability, what technologies will need to be developed to achieve this level of performance, and what steps need to be taken to develop the technology.

WORKING GROUP D:
GROUND ROBOTICS IN HOME-LAND DEFENSE:

This session will focus on robotics in the NORTHCOM mission areas. The session will assess the impacts that robotics have on their mission areas, the need for advanced robotic technologies, and the development of plans for obtaining these capabilities.

MONDAY, MARCH 3

3:00-6:30 PM	Onsite Registration
5:00-6:30 PM	Grand Opening Reception in Exhibit Hall

TUESDAY, MARCH 4

7:00 AM	Continental Breakfast/Registration
8:00 AM	Opening Remarks – *Mr. David Ahern*, Director, Portfolio Systems Acquisition, Acquisition, Technology and Logistics, OUSD
8:30 AM	Keynote Speaker – *GEN Paul Kern, USA (Ret)*
9:00 AM	Guest Speaker – *BG Irardi*, (JTF-N CG)
9:30 AM	Break in Exhibit Hall
10:00 AM	OSD Ground Robotics Update – *Mrs. Ellen Purdy*, Director, Joint Ground Robotics Enterprise, Acquisition, Technology and Logistics, OUSD
10:30 AM	Keynote Panel – Warfighter Perspective / Needs
	Chair - *COL Russell Hrdy, USA*, Deputy Director, US Army Armament Research and Development Center
12:00 PM	Lunch
1:30-5:00 PM	TRACK A - Paper Presentations (Paper order is subject to change)
	Intelligent Modular Manipulation for Mobile Robots, *Mr. Jorgen Pedersen*
	Robotics and the Law of War, *COL Richard Jackson, USA (Ret)*
	Virtual Autonomous Navigation Environment (VANE), *Mr. Randolph Jones*
	Improving Endurance of Unmanned Ground Vehicles, *Mr. John Hart*
	Understanding the Benefits and Limitations of Autonomy for Critical UGV Tactical Operations, *Mr. David Bruemmer*
	Improving Reliability of EOD Robots with Systems Health Management, *Mr. Chris Rogan P.E.*
1:30-5:00 PM	Working group B – Small Business Issues
	Working group C – Technology "Longpoles"
	Working group D – Ground Robotics In Homeland Defense
5:00-6:00 PM	Reception in Exhibit Hall
6:00-8:00 PM	Banquet Dinner

WEDNESDAY, MARCH 5

7:00 AM	Continental Breakfast/Registration
8:00 AM	Opening Remarks
8:15 AM	Keynote Speaker – *Mr. Rodney Brooks*, iRobot
9:00 AM	Guest Speaker – Automotive Company
9:30 AM	Break in Exhibit Hall
10:00 AM	Keynote Panel – International
12:00 PM	Lunch
1:30 – 5:00 PM	TRACK E - Paper Presentations (Paper order is subject to change)
	Army Combat Casualty Care Collaborative Robotics & Telerobotics for Multiple Missions, *Dr. Gary Gilbert, PhD*
	Effective User Interfaces for Human-Robot Collaboration in Dismounted Operations, *Dr. Candace Sidner*
	AEODRS - The Fourth Generaition EOD Robot, *Mr. Byron Brezina*
	Supporting Robotics in a War Environment, *Mr. Jerry Decker*
	Optimal Search Strategies for Teams of UXO Hunting Robots, *Mr. Stephen Tully*
	Intelligent Radios with Integrated Video for Ground Robotics, *Mr. Ricky Houghton*
1:30 – 5:00 PM	Working Group F – Combat Support/Combat Service Support Issues
	Working Group G – Operational Issues/Challenges
	Working Group H – Interoperability
4:00 PM	Exhibits Close
5:00 PM	Adjourn for the day

THURSDAY, MARCH 6

7:00 AM	Continental Breakfast/Registration
8:00 AM	Opening Remarks
8:15 AM	Keynote Speaker – *Mr. Richard Rumpf*, Former Acting Assistant Secretary of the Navy for Research, Engineering and Systems; Rumpf Associates International
9:00 AM	Tracks B-D and F-H Working Sessions Results
11:30 AM	Conference Wrap-up
12:00 PM	Conference Adjourned

WORKING GROUP DESCRIPTIONS

WORKING GROUP F:
COMBAT SUPPORT/COMBAT SERVICE SUPPORT ISSUES:

Much of the focus for today's unmanned systems technologies is on the critical need to defeat IEDs. The focus of this break out session will be to identify potential uses of unmanned systems to support CS/CSS mission areas and the associated technologies, and develop courses of action to increase the speed with which these capabilities can be provided to the Warfighters.

WORKING GROUP G:
OPERATIONAL ISSUES/CHALLENGES:

This session will have multiple topics, ranging from the laws of armed conflict to instilling trust in the use of unmanned systems to the need for full autonomy. Each of these topics, among others, will be assessed and steps developed to overcome them.

WORKING GROUP H:
INTEROPERABILITY:

The importance of interoperability continues to grow as more unmanned systems – including ground, air, sea, and underwater vehicles – are fielded. Most visibly, the Joint Architecture for Unmanned Systems (JAUS) and NATO's Standardization Agreement "STANAG" 4586 enjoy considerable attention. An examination of interoperability standards for unmanned systems is the focus of this breakout session, as well as developing a path forward for achieving these roles.

EXHIBITOR INFORMATION

To reserve a booth online go to the NDIA web site: http://exhibits.ndia. org. If you have questions, please contact Ms. Alden Davidson, Exhibits Manager at phone: (703) 247-2582; email: adavidson@ndia.org.

Exhibitors please note: Each company gets two full conference registrations with each 10x10 booth. If you are supposed to be registered as exhibit personnel, please verify with Alden Davidson to check on your badges. After the two complimentary registrations have been taken, you will need to register on the conference side for your badge.

EXHIBIT HOURS

Monday, March 3, 2008
5:00 PM - 6:30 PM

Tuesday, March 4, 2008
9:00 AM - 6:00 PM
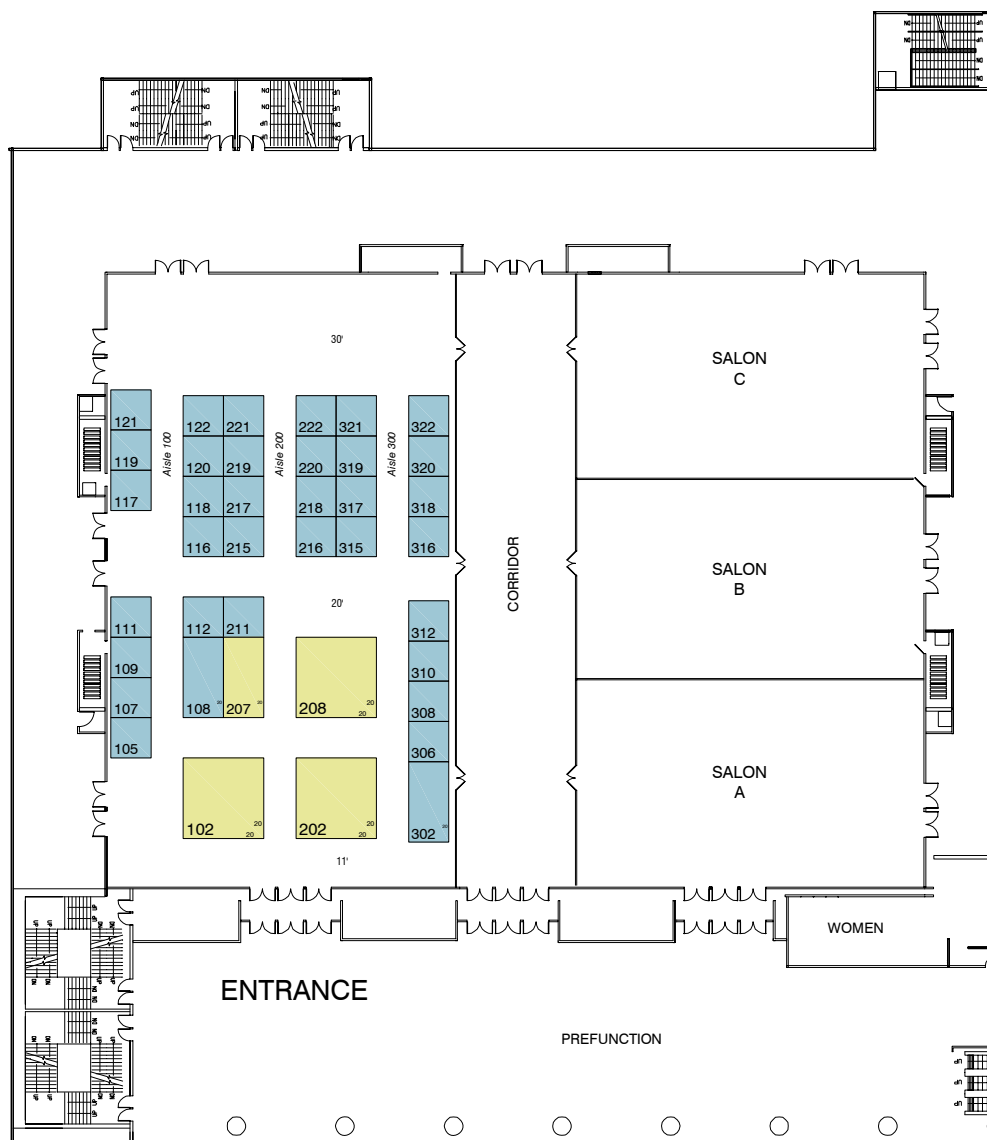
Wedneday, March 5, 2008
9:00 AM - 4:00 PM

Visit the following web link to to purchase a booth:

http://exhibits.ndia.org/exhibits/8380

EXHIBIT FLOOR PLAN

Rev. 11/14/07

Texas Ballroom D/E/F
51-10x10 booths
Aisle widths 8' unless noted

SPONSORSHIP INFORMATION

GRAND OPENING RECEPTION SPONSOR (AVAILABLE TO 2 SPONSORS):
Investment: $10,000 each (Monday only)

TUESDAY NIGHT RECEPTION AND BANQUET DINNER SPONSOR (AVAILABLE TO 2 SPONSORS):
Investment: $10,000 each (Tuesday only)

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Investment: $6,000 each (Tuesday, Wednesday, and Thursday)

LUNCH SPONSORSHIP (AVAILABLE TO 1 ADDITIONAL SPONSOR):
Investment: $9,000 each (Tuesday Lunch Sponsorship sold to Foster-Miller, Inc.)

ATTENDEE EXECUTIVE PADFOLIO SPONSORSHIP (LIMITED TO ONE SPONSOR):
Investment: $6,000 (if Sponsor provides insert) $7,000 (if NDIA provides insert)

COFFEE BREAK SPONSORSHIP (AVAILABLE TO 2 SPONSORS):
Investment: $3,000 each (Tuesday and Wednesday morning)

INTERNET CAFÉ SPONSORSHIP (LIMITED TO ONE SPONSOR):
Investment: $5,000 for all four days

LANYARDS:
What better way to market your company everyday of the conference than to have your logo printed on lanyards which will hold name badges for the attendees and exhibitors.
Investment: $3,000

LITERATURE INSERT SPONSORS: (available to three sponsors): Inserting 300, one page flyers into all the attendee padfolios (if available) or handed out with the on-site agenda is a great way to promote a new product or service. Company provides the promotional flyer materials.
Investment: $2,000 (If NDIA prints the insert, investment increases to $2,500)

To receive more information please contact Alden Davidson, Exhibits and Sponsorships Manager, at 703-247-2582 or email: adavidson@ndia.org or Laura Hoover, Sponsorship Manager, at 804-437-3773 or email: lhoover@ndia.org.

HOTEL INFORMATION

Please use the following link to make your reservations at the Grand Hyatt San Antonio:

https://resweb.passkey.com/Resweb.do?mode=welcome_ei_new&eventID=54994fromResdesk=true.

You can also find this link on the NDIA website at www.ndia.org/meetings/8380. (when making your reservations via the above link click on "Search Available Rooms" then select either "Government" or "Industry" under the pull down menu).

An access code is not required to make a hotel reservations however you will have to show active duty or civilian government identification when you check into the hotel.

NDIA personal will monitor the block for reservation accuracy. Rooms will not be held after Thursday, February 14, 2008 and may sell out before then. Rates are also subject to increase after this date. The current per diem rate at the Grand Hyatt San Antonio is $112 plus $25 for each additional person. The industry room rate is $189 for single occupancy and $214 for double occupancy.

Please visit www.gsa.gov for more information on the government per diem rates.

CONFERENCE REGISTRATION FEES	EARLY (UNTIL 1/18)	REGULAR (1/19-2/15)	LATE AFTER (2/15)
GOVERNMENT/ ACADEMIA/ ALLIED GOV.	$550	$605	$665
INDUSTRY NDIA MEMBER	$745	$820	$895
INDUSTRY NON-NDIA MEMBER	$795	$875	$965

REGISTRATION - THERE ARE THREE WAYS TO REGISTER

ONLINE

Our preferred method of registration is online. Please visit www.ndia.org/meetings/8380 to register online.

FAX

Register via fax by completing the Registration Form and faxing it to (703) 522-1885. Please do not fax any registrations after February 15, 2007. After this date, please bring your completed registration form with you to the conference to register on-site.

MAIL

Registration Forms may be mailed to: NDIA, Event #8380, 2111 Wilson Blvd., Suite 400, Arlington, VA 22201. Please do not mail any registrations after February 15. After this date, please bring your completed registration form with you to the conference to register on-site or register online. Registrations will not be taken over the phone. Payment must be made at the time of registration.

CANCELLATIONS

Cancellations before 01/18/08 receive a full refund. Cancellations between 01/18/08 - 02/15/08 receive a refund minus a $75 cancellation fee. No refunds for cancellations received after 2/15/08. Cancellations must be made in writing to Phyllis Edmonson via email at pedmonson@ndia.org. Substitutions welcome in lieu of cancellation!

SPECIAL NEEDS

NDIA supports the Americans with Disabilities Act of 1990. Attendees with special needs should contact Phyllis Edmonson, Meeting Planner, at (703) 247-2577, or via e-mail at pedmonson@ndia.org.

CONFERENCE ATTIRE

Appropriate dress for this conference is coat and tie for civilian and uniform of the day for military.

EVENT #8380 ► NDIA REGISTRATION FORM

NATIONAL DEFENSE INDUSTRIAL ASSOCIATION ► 2111 WILSON BOULEVARD, SUITE 400
ARLINGTON, VA 22201-3061 ►(703) 522-1820 ► (703) 522-1885 FAX ► WWW.NDIA.ORG

2008 GROUND ROBOTICS CAPABILITIES CONFERENCE & EXHIBITION ►GRAND HYATT SAN ANTONIO HOTEL
SAN ANTONIO, TX MARCH 3-6, 2008

3 Ways to sign up: 1. Online with a credit card at www.ndia.org
2. By fax with a credit card — Fax: 703-522-1885
3. By mail with a check or credit card

☐ Address change needed

NDIA Master ID/Membership # _____
(if known—hint: on mailing label above your name)

Social Security # _____
(last 4 digits – optional)

Prefix _____
(e.g. RADM, COL, Mr., Ms., Dr., etc.)

Name First _____ MI_____ Last _____

Military Affiliation _____
(e.g. USMC, USA (Ret.) etc.)

Nickname_____
(for Meeting Badges)

Title _____

Organization _____

Street Address _____

Address *(Suite, PO Box, Mail Stop, Building, etc.)*_____

City _____ State _____ Zip _____ Country _____

Phone _____ ext. _____ Fax _____

E-Mail _____

Signature* _____ Date _____

Preferred way to receive information

Conference information   ☐ address above   ☐ Alternate *(print address below)*   ☐ E-mail

Subscriptions   ☐ address above   ☐ Alternate *(print address below)*

Alternate Street Address _____

Alternate Address *(Suite, PO Box, Mail Stop, Building, etc.)* _____

City _____ State _____ Zip _____ Country _____

* By your signature above you consent to receive communications sent by or on behalf of NDIA, its Chapters, Divisions and affiliates (NTSA, AFEI, PSA, NCWG, WID) via regular mail, e-mail, telephone, or fax. NDIA, its Chapters, Divisions and affiliates do not sell data to vendors or other companies.

CONFERENCE REGISTRATION FEES	Early (before 01/18/08)	Regular	Late (after 02/15/08)
Government/Academia/Allied[1]	☐$550	☐$605	☐$665
Industry NDIA member and affiliates (AFEI, NTSA, PSA, WID)	☐$745	☐$820	☐$895
Industry non-NDIA member[2]	☐$795	☐$875	☐$965

Cancellations before 01/18/08 receive a full refund. Cancellations between 01/15/08-02/15/08 receive a refund minus a $75 cancellation fee. No refunds for cancellations received after 02/15/08. Substitutions welcome in lieu of cancellations!

[1] Includes a free three-year NDIA membership and subscription to National Defense magazine for military and government employees (fi rst time members only). ☐ No, do not sign me up for the Government membership.

[2] Includes a free one-year NDIA membership and subscription to National Defense magazine.

PAYMENT OPTIONS
☐ Check (Payable to NDIA - Event #8380)   ☐ Government PO/Training Form #
☐ VISA   ☐ MasterCard   ☐ American Express   ☐ Diners Club   ☐ Cash
If paying by credit card, you may return by fax to (703) 522-1885.

Credit Card Number _____ Exp. Date _____

Signature _____

By completing the following, You Help Us Understand Who Is Attending Our Meetings.

PRIMARY OCCUPATIONAL CLASSIFI-CATION. Check ONE.
► A. Defense Business/Industry
► B. R&D/Laboratories
► C. Army
► D. Navy
► E. Air Force
► F. Marine Corps
► G. Coast Guard
► H. DOD/MOD Civilian
► I.   Government Civilian (Non-DOD/MOD)
► J. Trade/Professional Assn.
► K. Educator/Academia
► L. Professional Services
► M. Non-Defense Business
► N. Other

CURRENT JOB/TITLE/POSITION. Check ONE.
► A. Senior Executive
► B. Executive
► C. Manager
► D. Engineer/Scientist
► E. Professor/Instructor/Librarian
► F. Ambassador/Attaché
► G. Legislator/Legislative Aide
► H. General/Admiral
► I. Colonel/Navy Captain
► J. Lieutenant Colonel/Commander/Major/Lieutenant Commander
► K. Captain/Lieutenant/Ensign
► L. Enlisted Military
► O. Other

Year of birth _____

QUESTIONS, CONTACT:
Ms. Phyllis Edmonson,
Meeting Planner
Phone: (703) 247-2577
E-mail: pedmonson@ndia.org

Mail Registration To:
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2111 Wilson Boulevard
Suite 400
Arlington, VA 22201

NDIA
NATIONAL DEFENSE INDUSTRIAL ASSOCIATION
STRENGTH THROUGH INDUSTRY & TECHNOLOGY

2008 GROUND ROBOTICS CAPABILITIES CONFERENCE & EXHIBITION

TO REGISTER, VISIT:
WWW.NDIA.ORG/MEETINGS/8380

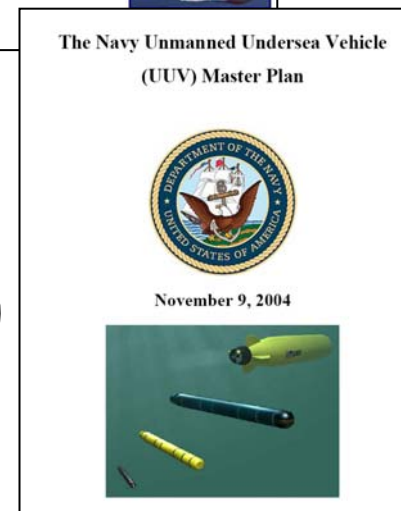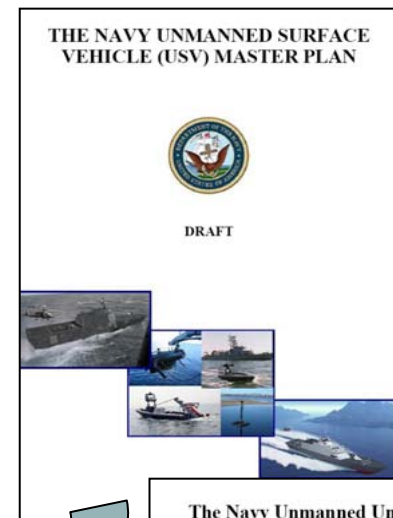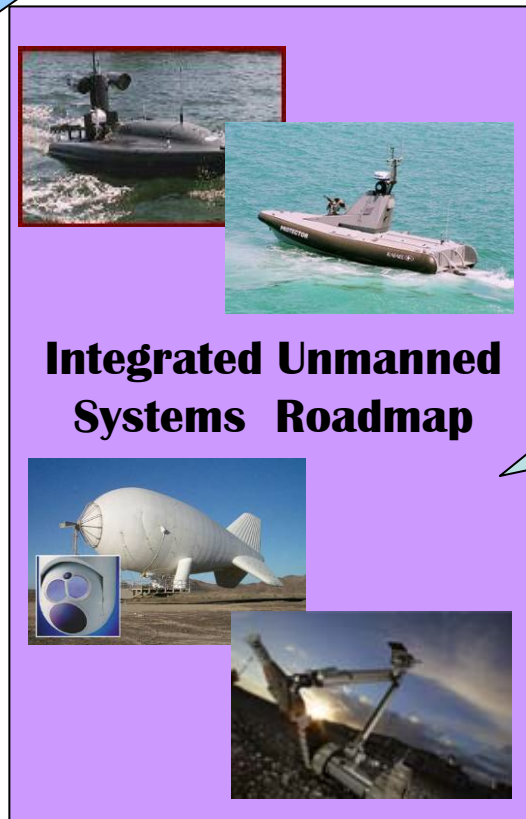# *DoD Unmanned Systems Integrated Roadmap*

Presented at the Ground Robotics Capability Conference

4 March 2008

Mr. David Ahern

OUSD(ATL)/PSA

david.ahern@osd.mil

Integrated Unmanned Systems Roadmap

Public Law 109-364 SEC 941

REPORT. – Not later than 120 days after the date of the enactment of this Act, the Secretary shall submit to the congressional defense committees a report containing –

- the policy required by subsection (a); and an ==implementation plan== for the policy that includes –
    - ==a strategy and schedules for the replacement of manned systems with unmanned systems in the performance of the mission identified in the policy pursuant to subsection (b)(1);==
    - ==establishment of programs to address technical, operational, and production challenges, and gaps in capabilities, with respect to unmanned systems; and==
    - an assessment of progress towards the goals identified for the subset of unmanned air and ground systems established in section 220 of the Floyd D. Spence National Defense Authorization Act for Fiscal Year 2001 (as enacted into law by Public Law 106-398; 114 Stat. 1654A-38).

UNMANNED SYSTEMS DEFINED. – In this section, the term "unmanned systems" consists of unmanned aerial systems, unmanned ground systems, and unmanned maritime systems.

Roadmap Introduction

The Unmanned Systems Integrated Roadmap is a master plan that describes the intended future state of the Unmanned Systems Product Line Portfolios and the actions to be undertaken to achieve that future state.

The Roadmap will serve to inform future decision making associated with the management of the Unmanned System Portfolios as they provide needed capabilities to the joint Warfighter.

Purpose

• The Purpose of the Unmanned Systems Integrated Roadmap is to project a future vision for how unmanned systems will be developed, acquired, and sustained as part of the materiel employed by the DoD.

• The Roadmap will:
  • Identify recommended intermediate states of advancement along the way to achieving that vision

  • Identify Strengths, Weakness, Opportunities, Challenges, and Risks associated with achieving that future vision

  • Identify those actions and responsible organizations that will capitalize on the strengths and opportunities, and mitigate the challenges and risks

  • Be responsive to plans, concerns, and issues of DoD, Services and organizations as well as Statute and Congressional Intent

Scope

The Scope of the Roadmap will address:

- The 3 Product Line Portfolios:
    - Unmanned Aircraft Systems
    - Unmanned Ground Vehicles
    - Unmanned Maritime Systems (Surface and Undersea)

- from 2009 – 2034

- technology development, standardization, interoperability, joint acquisition, policy

The Roadmap will not address:

- detailed operational concepts for employing unmanned systems

- operational requirements for unmanned systems

Addressing Capability Needs via Unmanned "Means" (notional)

2009   2034

JCA 1- Battlespace Awareness	RECONNAISSANCE-UAS, SIGINT COLLECTION-UAS, MAN-PORTABLE EOD-UGV, GLOBAL HAWK-UAS, INFORMATION OPERATIONS-UUS
JCA 4- Force Application	TACTICAL STRIKE-UAS, INTEGRATED STRIKE-UAS, MINE WARFARE-USV, TIME CRITICAL STRIKE-UUS, PENETRATING STRIKE-UAS
JCA 5- Protection	MARITIME PATROL-UUS, HULL UUV LOCALIZATION SYSTEM-UUV, MULE-UGV, ACTIVE RANGE CLEARANCE-UGV, SUGV-UGV, MINE NEUTRALIZATION-UGV, COUNTERAIR-UAS
JCA 6- Logistics	CONVOY OPERATIONS-UGV, AIRLIFT-UAS, AERIAL REFUELING-UAS, MANUEVER SUPPORT & SUSTAINMENT-UGV, MULE-UGV

7

Unmanned Systems Performance Evolution (notional)

Human Intervention High (left axis) | **Autonomy /Intelligence High** (right axis)

2009	Evolutionary Adaptation	20??	Revolutionary Adaptation	2034

#				
1	Individual System	Teaming w/in Domain	Collaboration across domains	Teamed Collaboration
2	Spectrum Constrained RF		Spectrum Independent - Hopping	
3	Mission Endurance in hours	Mission Endurance in days		Mission Endurance in weeks
4	Mission Complexity – operator controlled	Route Planning	Obstacle Avoidance	Adaptive Tactical Behaviors
5	Limited Environmental Difficulty		Expanded Environmental Difficulty	
6	Mission Package Product Line Dependant		Product Line Independent	
7	OPSEC – Signature High		OPSEC – Signature Low	
8	Operational Control N:1 1:1 1:# w/in Domain 1:# across domains 1:# Teamed			
9				

8

Unmanned Systems Technology Enablers (notional)

| 2009 | Evolutionary Adaptation | 20?? | Revolutionary Adaptation | 2034 |
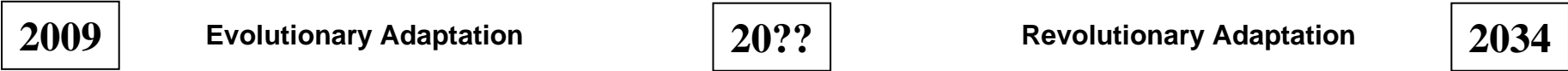
#				
1	Battery Powered	Hybrid Electric	Fuel Cell	Solar Powered
2	Spectrum Constrained RF	Frequency Hopping		Non-RF Comms
3	Mild Weather			All Weather
4	Passive Signature Management			Active Signature Management
5	Architecture Proprietary/Limited	Architecture Standard		Architecture Standard Unlimited
6				
7				
8				
9				

Tasking Memo

THE UNDER SECRETARY OF DEFENSE
3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

ACQUISITION,
TECHNOLOGY
AND LOGISTICS

FEB 01 2008

MEMORANDUM FOR UNDER SECRETARY OF DEFENSE FOR INTELLIGENCE
DIRECTOR, DEFENSE RESEARCH & ENGINEERING
ASSISTANT SECRETARY OF DEFENSE (HOMELAND
DEFENSE AND AMERICAS' SECURITY AFFAIRS)
ASSISTANT SECRETARY OF DEFENSE (NETWORK
AND INFORMATION INTEGRATION)
SERVICE ACQUISITION EXECUTIVES
DIRECTOR, PROGRAM ANALYSIS AND EVALUATION
DIRECTOR, DEFENSE ADVANCED RESEARCH
PROJECTS AGENCY
DIRECTOR, NATIONAL GEOSPATIAL-INTELLIGENCE
AGENCY
JOINT STAFF, J-8
ARMY DEPUTY CHIEF OF STAFF (G-8)
DEPUTY CHIEF OF NAVAL OPERATIONS
(INTEGRATION OF CAPABILITIES AND RESOURCES)(N8)
DIRECTOR, OPERATIONAL CAPABILITY REQUIREMENTS
HEADQUARTERS, UNITED STATES AIR FORCE (A5)

SUBJECT: Unmanned Systems Integrated Roadmap, 2009-2034

Public Law 109-364, section 941, requires the Secretary of Defense to establish an implementation plan to address technical, operational, and production challenges and gaps in capabilities with regard to unmanned systems. The purpose of the FY09-34 *Unmanned Systems Integrated Roadmap* is to project a future vision for how unmanned systems will be developed, acquired, and sustained to ensure DoD compliance with PL 109-364. It will address all three Product Line Portfolios: Unmanned Aircraft Systems, Unmanned Ground Vehicles, and Unmanned Maritime Systems (Surface and Undersea).

My office has developed a strategy to produce the Roadmap by the end of this calendar year. This strategy involves a Subject Matter Expert Working Group from Department laboratories and Program Offices to link capability needs identified by the Joint Capability Areas with unmanned system technologies from all three domains. An Integration Team composed of representatives from my office, the Joint Staff, Service headquarters, and other OSD and Department agencies will synchronize the results of the Working Group to ensure a logical plan consistent with the Public Law.

By February 12, request you assign Air, Land and Sea systems action officers (AOs) to support this effort. AOs for the Integration Team should be at the O-6 level and at the subject matter expert level for the Working Group. We intend to have a kick-off meeting for the Roadmap in mid-February.

We appreciate your staffs' support in developing a new Integrated Roadmap. My points of contact for the Roadmap are Mrs. Ellen Purdy, 703-693-9617, for Ground Vehicles; Mr. Dyke Weatherington, 703-695-6188, for Aircraft Systems; and Lieutenant Commander Rick Myers, 703-697-2423, for Maritime Systems.

John J. Young, Jr.

cc:
USJFCOM

2

Planning Organization

Senior Council populated
by PSA, DDRE, Joint
Staff, Services GO/SES

**Unmanned Systems
Roadmap
Senior Council**

**Roadmap Planning
Integration Team**

Integration Team populated by
PSA Domain reps, DDRE, Joint
Staff, Other DoD Orgs, Service
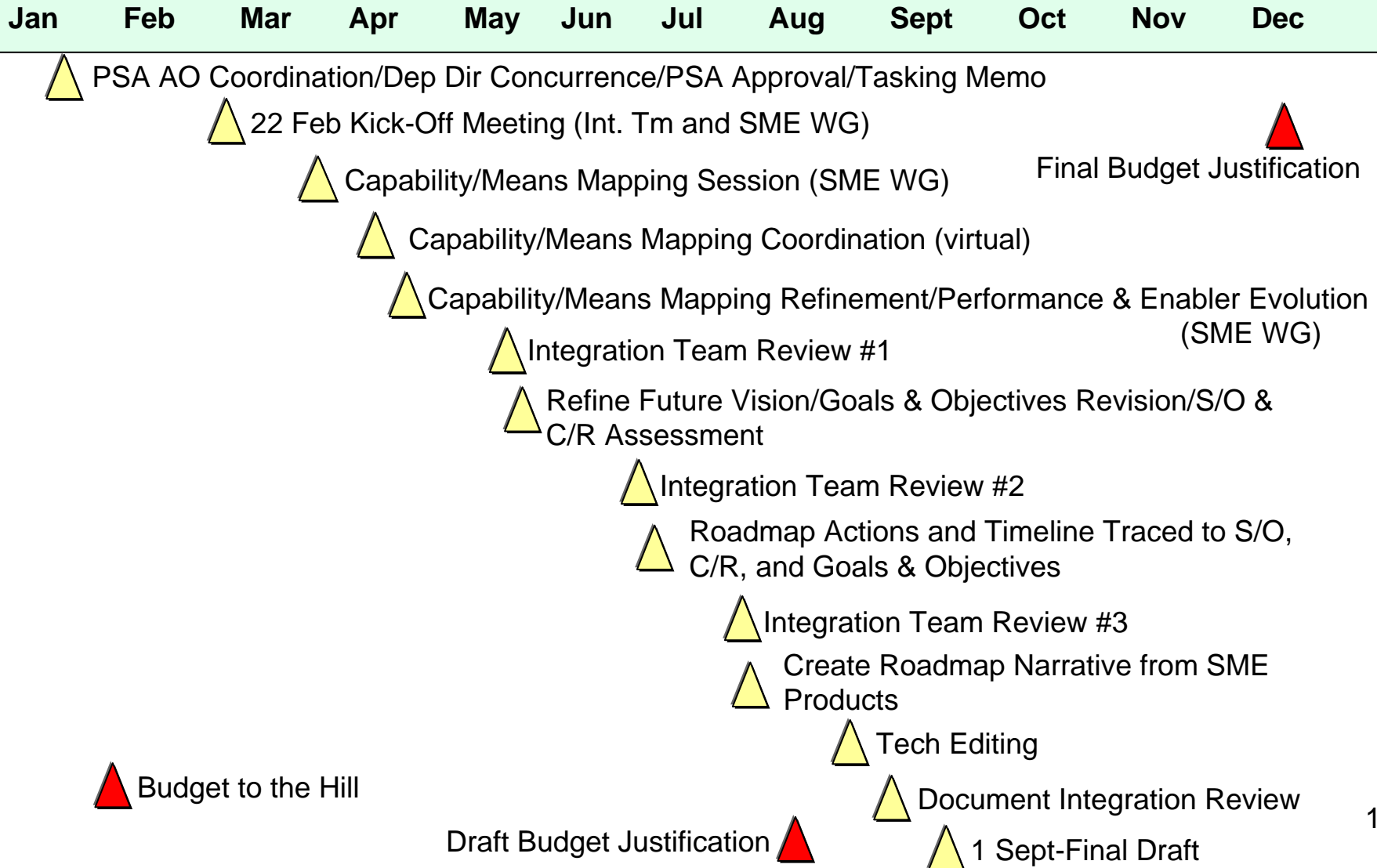HQs at 06 level

**Strengths/
Opportunities
Sub-WG**

**Subject Matter Expert Working Group
WG**

**Challenges/
Risk
Sub-WG**

Working Groups populated by Subject Matter Experts from DoD labs, Program Offices,
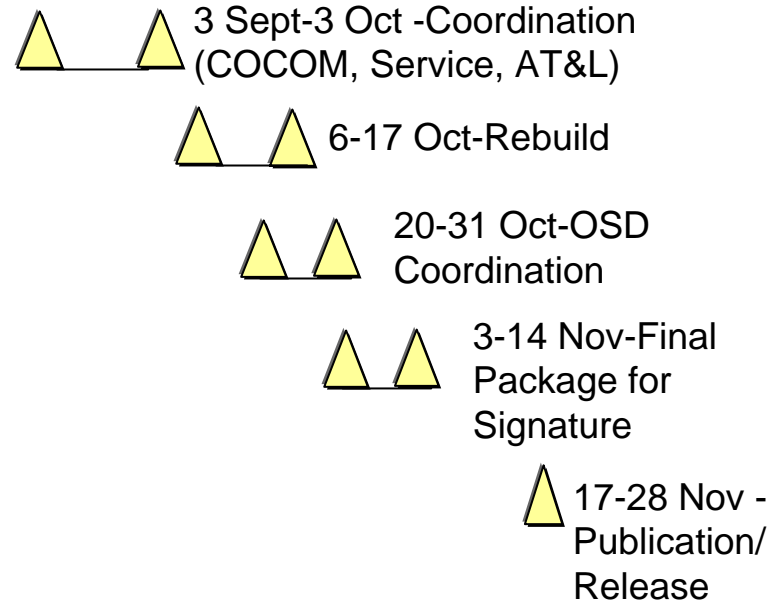other as needed

Roadmap "Battle Rhythm" FY08-FY09

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec

PSA AO Coordination/Dep Dir Concurrence/PSA Approval/Tasking Memo

22 Feb Kick-Off Meeting (Int. Tm and SME WG)

Final Budget Justification

Capability/Means Mapping Session (SME WG)

Capability/Means Mapping Coordination (virtual)

Capability/Means Mapping Refinement/Performance & Enabler Evolution (SME WG)

Integration Team Review #1

Refine Future Vision/Goals & Objectives Revision/S/O & C/R Assessment

Integration Team Review #2

Roadmap Actions and Timeline Traced to S/O, C/R, and Goals & Objectives

Integration Team Review #3

Create Roadmap Narrative from SME Products

Tech Editing

Budget to the Hill

Document Integration Review

Draft Budget Justification

1 Sept-Final Draft

12

Roadmap "Battle Rhythm" FY08-FY09 (continued)

Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec

3 Sept-3 Oct -Coordination (COCOM, Service, AT&L)

6-17 Oct-Rebuild

20-31 Oct-OSD Coordination

3-14 Nov-Final Package for Signature

17-28 Nov - Publication/ Release

Appropriations

Authorizations

13

Conclusions

- The 2009 Integrated Roadmap represents the first attempt to create our path forward across all the Domains from the bottom up.

- The Roadmap will represent a vision of how robotics can potentially satisfy capability needs, but that does not equate to all future needs being answered by robots.

- The Roadmap seeks to "connect the dots" between future capabilities, unmanned systems performance, and enabling technologies so that we focus our investments into critical need areas.

- The Roadmap will address unmanned systems from a product line portfolio perspective. The idea is to recognize opportunities and minimize risks so that we capitalize sooner and more efficiently on what unmanned systems can do for DoD.
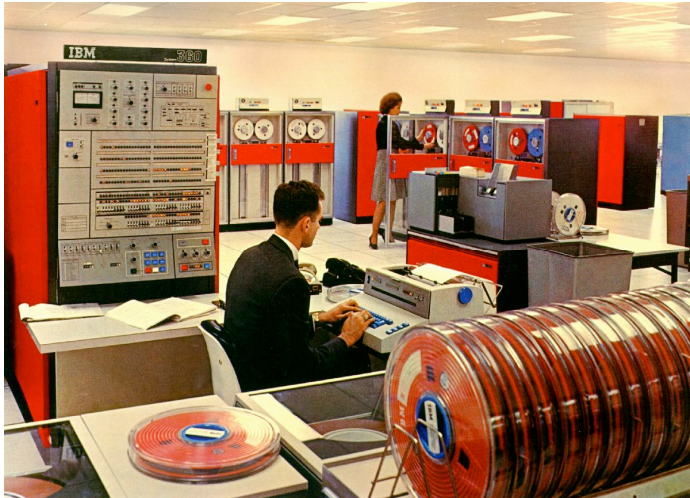
Technology and Other Trends

Rodney Brooks

Panasonic Professor of Robotics, MIT CSAIL

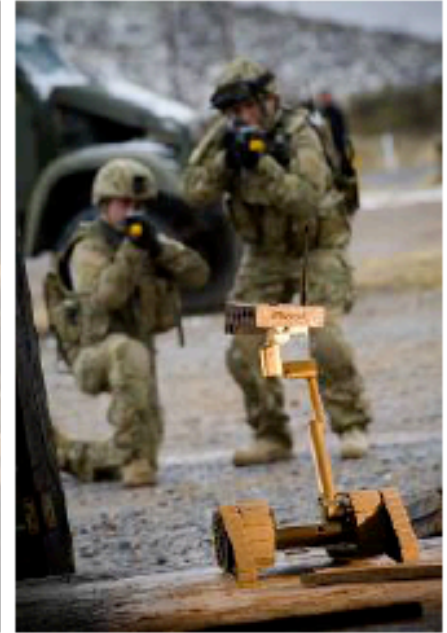CTO, iRobot Corporation

Two Revolutions

- Was
  - large corporate back room operation
  - automation slow and by specialized engineers

- Now
  - personal machines
  - office workers automate their own work and increase their own productivity

???

SUGV at Experiment 1.1

Big Trends for Robotics

- Technology exponentials driven by others
- First technology exponentials driven by robots

- Large scale military robot deployments

- Aging population
- Increased health costs
- Immigration backlash
- Globalization backlash
- Future of transportation
- Carbon neutral energy

The experts look ahead

Cramming more components onto integrated circuits

With unit cost falling as the number of components per circuit rises, by 1975 economics may dictate squeezing as many as 65,000 components on a single silicon chip

By Gordon E. Moore

Director, Research and Development Laboratories, Fairchild Semiconductor division of Fairchild Camera and Instrument Corp.

Radical Insights

The future of integrated electronics is the future of electronics itself. The advantages of integration will bring about a proliferation of electronics, pushing this science into many new areas.

Integrated circuits will lead to such wonders as home computers—or at least terminals connected to a central computer—automatic controls for automobiles, and personal portable communications equipment. The electronic wristwatch needs only a display to be feasible today.

The Key Graph
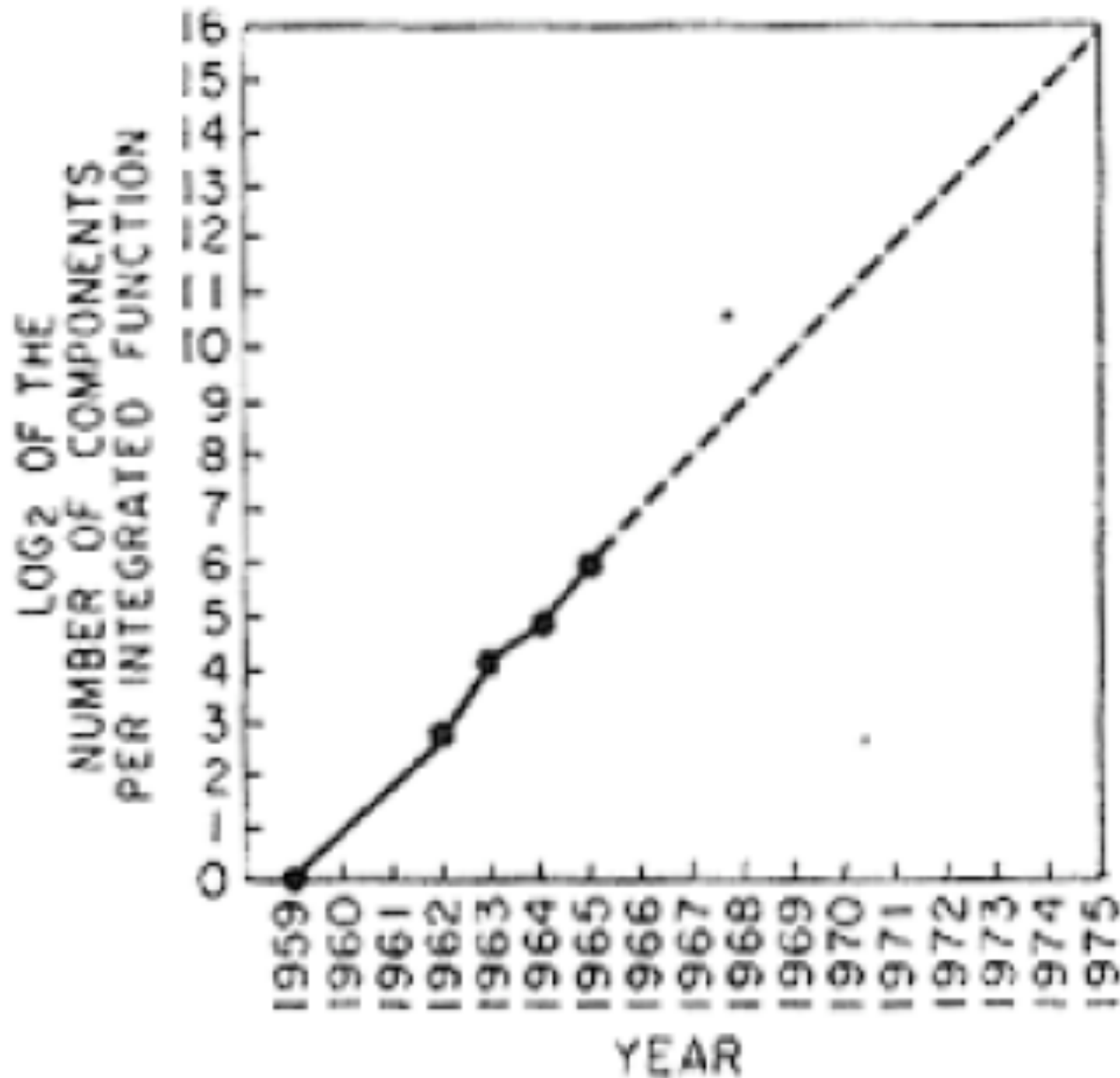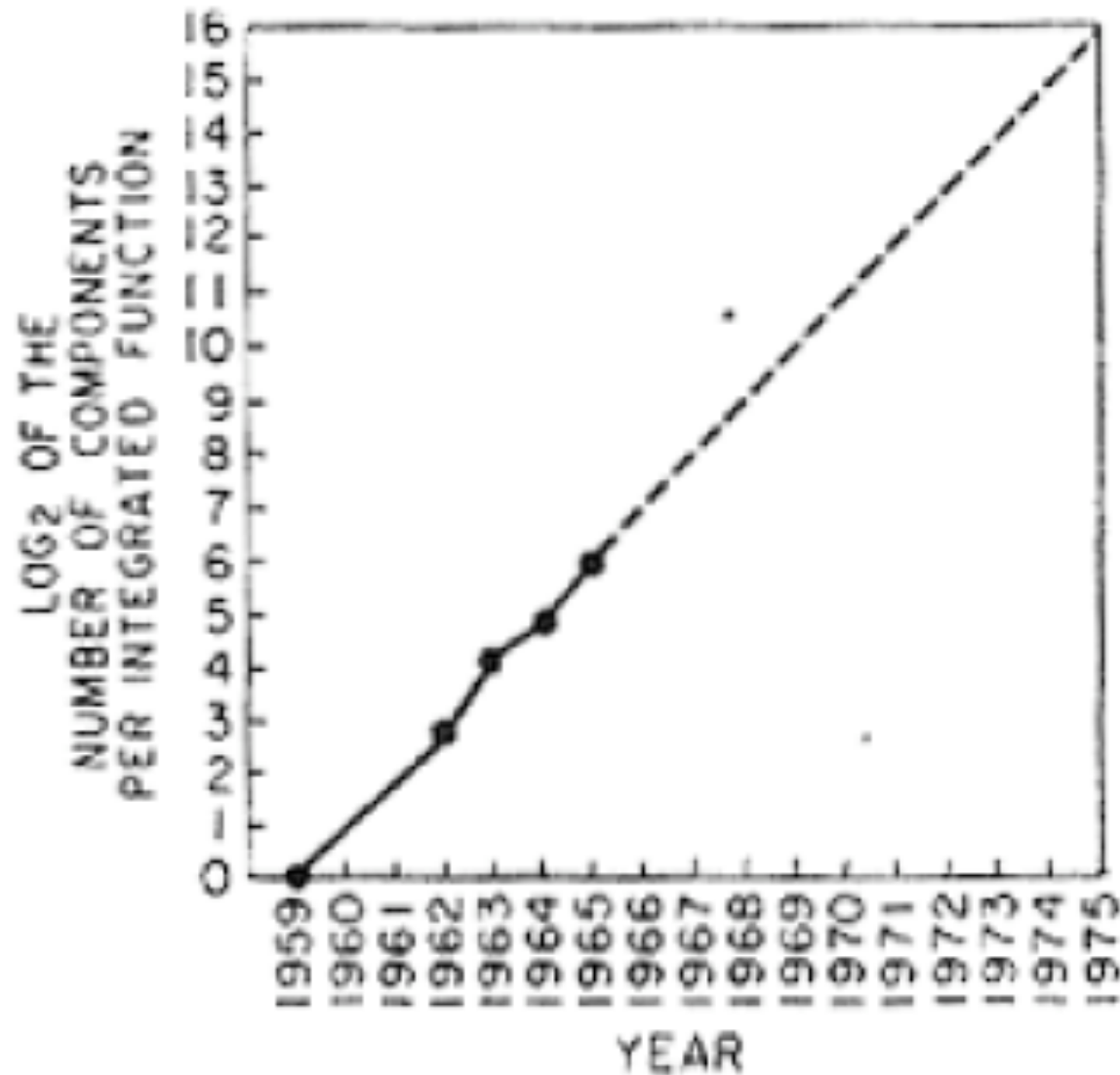
What Defines an Exponential?

$$\frac{ds}{dt} = \alpha s$$

- The rate of change of "stuff" is proportional to the instantaneous amount of "stuff" that is around already
- Is this the explanation for how computer power has been an exponential?
- Does the presence of computers of power P make it easier to build a computer of power wP, where w>1?

But Not in Play in 1965

Three Exponential Forms

1. Rate of improvement is proportional to the current level of adoption

2. The existence of the law tells everyone what level to aim for when

3. Someone else is driving an exponential and you get to hop on it for free

iPod as Current Storage Standard

CSAIL

- Mid 2003: 10 Gigabytes -- teenager price ($400), fits in pocket. Enough for most people's personal music collection.
- Mid 2004: 20 Gigabytes
- Mid 2005: (on Apple Web site):
  - 20 GB = $249
  - 30 GB = $349
  - 60 GB = $449 (sold as iPod Photo)
- Jan 2006 (on Apple Web site): 60 GB, $399 (thinner)
- Sept 2006 (finally): 80 GB, $349 [20,000 songs, 100 hrs video]
- Sept 2007: 160 GB, $349 (same March 4, 2008)
- Doubling every year
- That means an iPod in 2025, $400, will have

$$\$400 = 2^{(year-2003)} \times 10 \text{ Gigabytes}$$

  - 40,000,000 Gigabytes
  - or 40 Petabytes
- [iPod in 2015 will have 40,000 Gigabytes]
- [iPod in 2034 will have 2 Billion Gigabytes, i.e., 2 Exabytes]

iRobot

The Million Book Project (Raj Reddy)

CSAIL

- Digitization centers in India, China, Egypt
- Aim is 1,000,000 books digitized and freely available (now subsumed by Google)
- 500 Gigabytes as text (= iPod in 2009) [only 320,000 books now]
- 50 Petabytes as image files
- Library of Congress has 20 million books
  - 10,000 Gigabytes as text (= iPod in 2013)
- Current [2007] iPod = 200 hours of video (= 100+ movies)
- 379,871 movies on IMDb (? 800K including Bollywood)
- An iPod in 2020 will store 819,200 movies…
- All the ones worth caring about: <2016

iRobot

Exponential Consequence

Future robots, disconnected from the net,
can have enormous onboard databases.

Costs of Mechanical Components

	1993	1999	2000	2001	2003	2005	2006
Linear Bearing	$9.69	$10.02	$10.42	$10.71	$10.71	$11.60	$12.00
Ball Screw / inch	$2.12	$2.26	$2.26	$2.34	$2.39	$2.75	$2.75
Ball Nut	$124.09	$131.84	$131.84	$136.72	$139.46	$153.35	$155.65
Flexible Coupling	$17.58	$21.75	$22.30	$22.85	$22.85	$22.85	$22.85
Miter Gear	$11.57	$15.06	$13.02	$13.02	$13.40	$15.05	$15.76
100 MIPS[4][1]	$47.62	$2.78	$1.72	$1.06	$0.41	$0.16	$0.10
Relative C.P.I.[2]	1.000	1.055	1.138	1.222	1.219	1.305	1.476

Table A.1: Price trend data of precise mechanical parts and computation over time.[2]

Name	Description	McMaster-Carr
Linear Bearing	1/4"x1/2"x3/4" Frelon Lined Linear Bearing	#5986K2
Ball Screw / inch	1/2" Ball Screw (0.5" lead, 4150 Steel)	#5966K25
Ball Nut	1/2" Ball Nut (Mates with #5966K25)	#5966K15
Flexible Coupling	1/4"x1/4" (7 degree max) precision coupling	#6208K22
Miter Gear	Steel 20 degree Miter Gear (12px15x1/2" bore)	#6529K15

Relative Mechanical Costs over Time

	1993	1999	2000	2001	2003	2005	2006
Linear Bearing	1.000	0.980	0.945	0.904	0.907	0.917	0.839
Ball Screw/inch	1.000	1.010	0.937	0.903	0.925	0.994	0.879
Ball Nut	1.000	1.007	0.934	0.902	0.922	0.947	0.850
Flexible Coupling	1.000	1.173	1.115	1.064	1.066	0.996	0.881
Miter Gear	1.000	1.234	0.989	0.921	0.950	0.997	0.923

Moore's Law

- Even Gordon Moore is worried there is only another 10 years left
- "Solution" is multi-cores
  - BUT, parallel programming is not solved
- [At the same time handhelds are driving down power consumption]
- BUT, BUT, our robots can probably easily utilize 8 or so cores, without general parallel programming
  - dedication of individual cores to full blast processing (e.g., video comp., SLAM, etc.)
  - i.e., good days are here for robots

Yearly increase multiplier for
[instructions executed/second/$]

- Based on 1950-2000 data; perhaps it is getting faster, but assume constant (consv.).

- Factor is 1.45/year. Doubles in 1.88 years.

- E.g., 1MIP/$ in 1998 ==> 1.45MIP/$ in 1999

- Compared to a robot in 2007 this is how much computer power we'll have for same priced robot if we spend the same portion of COGS on computation

2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1.00	1.45	2.09	3.02	4.37	6.31	9.12	13.2	19.1	27.5	39.8

CSAIL

iRobot®

Exponential Consequence

When computation can be used to replace mechanical precision robots will get cheaper over time.

Exponentials and pseudo-E's for Robots

- Amount of computation
- # of cores on chip
- Onboard memory
- Pervasive wireless communication bandwidth
- Cost of sensors
  - cameras
  - auto collision sensors
  - nanotech-based sensors
- Installed base
  - user acceptance/familiarity
  - # of offerings
- Massive data sets on the WWW
  - machine learning
  - new vision algorithms
- Performance of speech systems
  - vocabulary, speaker independence, noise env.
- Smart automobiles
- Robots as teaching vehicles
  - college and high school

The Cart, in 1979

Stanford AI Lab

1979: 20 meters/6 hours

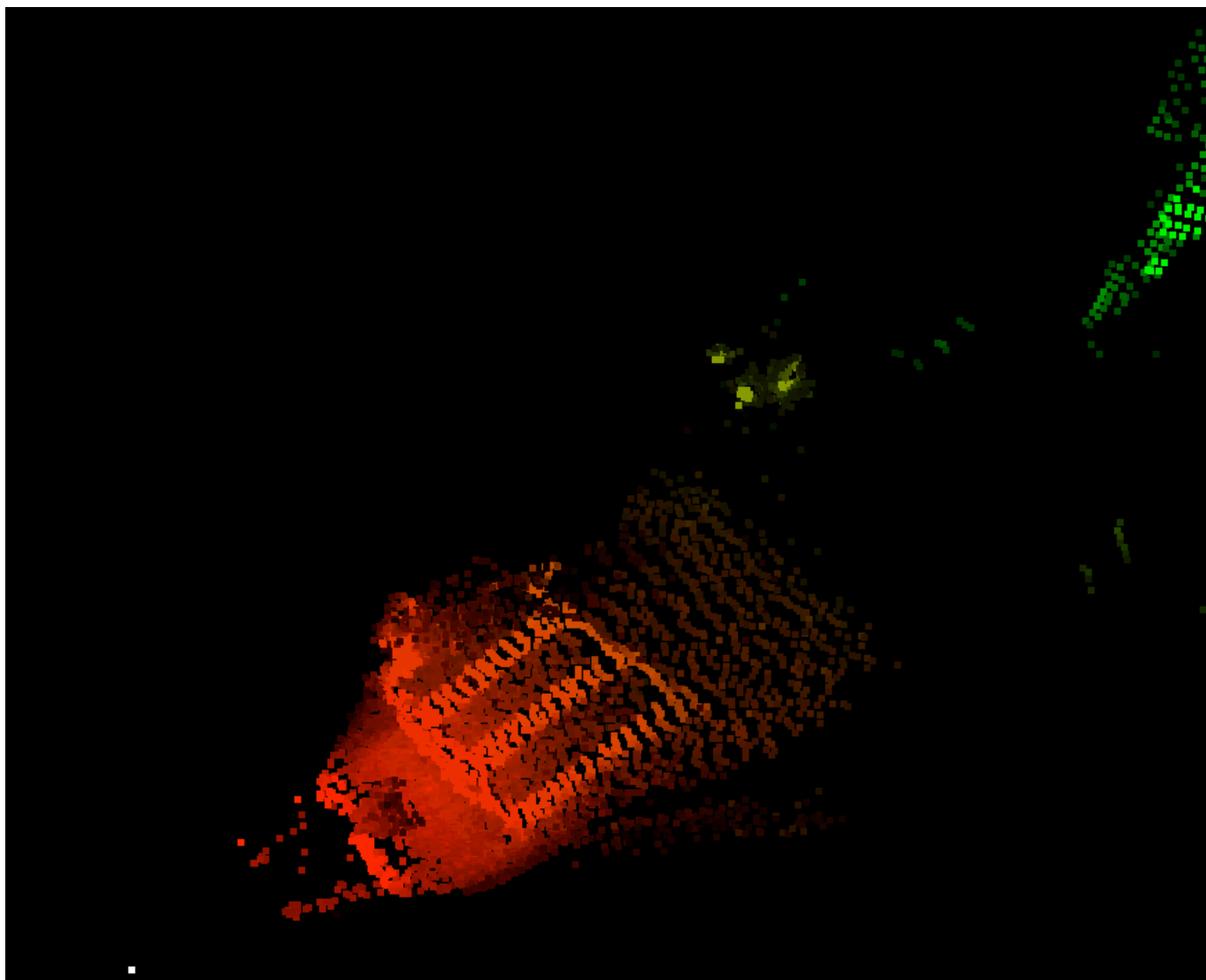4 orders of magnitude in 26 years
[doubles every 2 years]
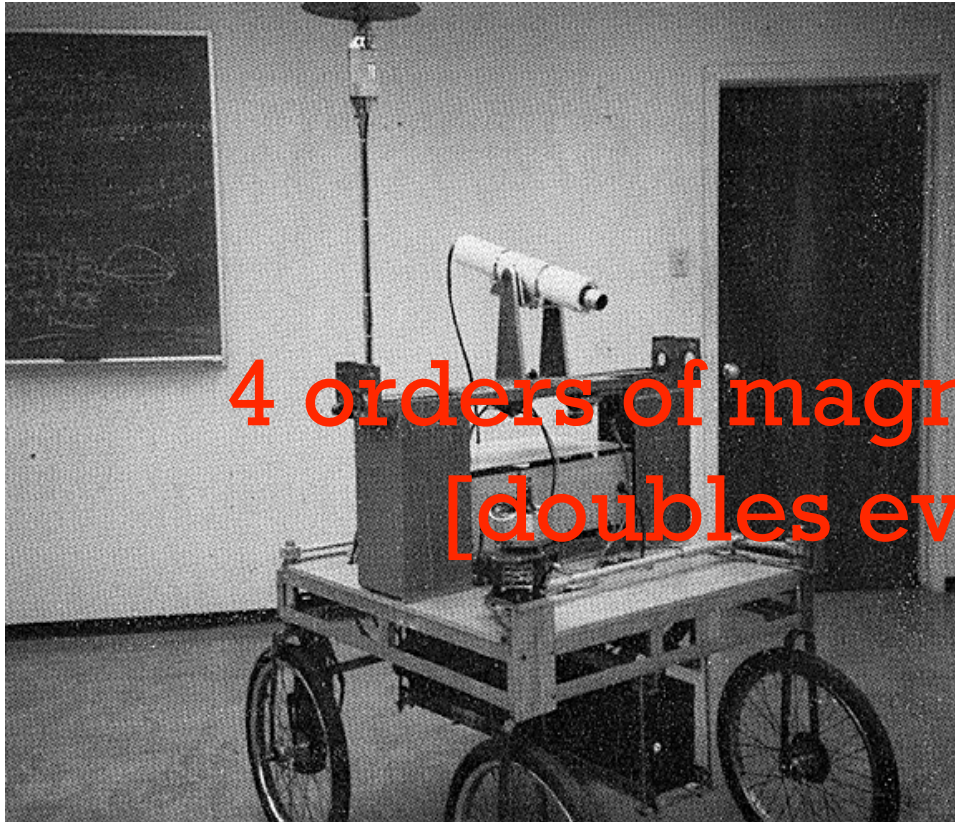
2005: 200 kilometers/6 hours

Robots As Drivers of Exponentials

Robots Requirements as Driver: ASC Sensor
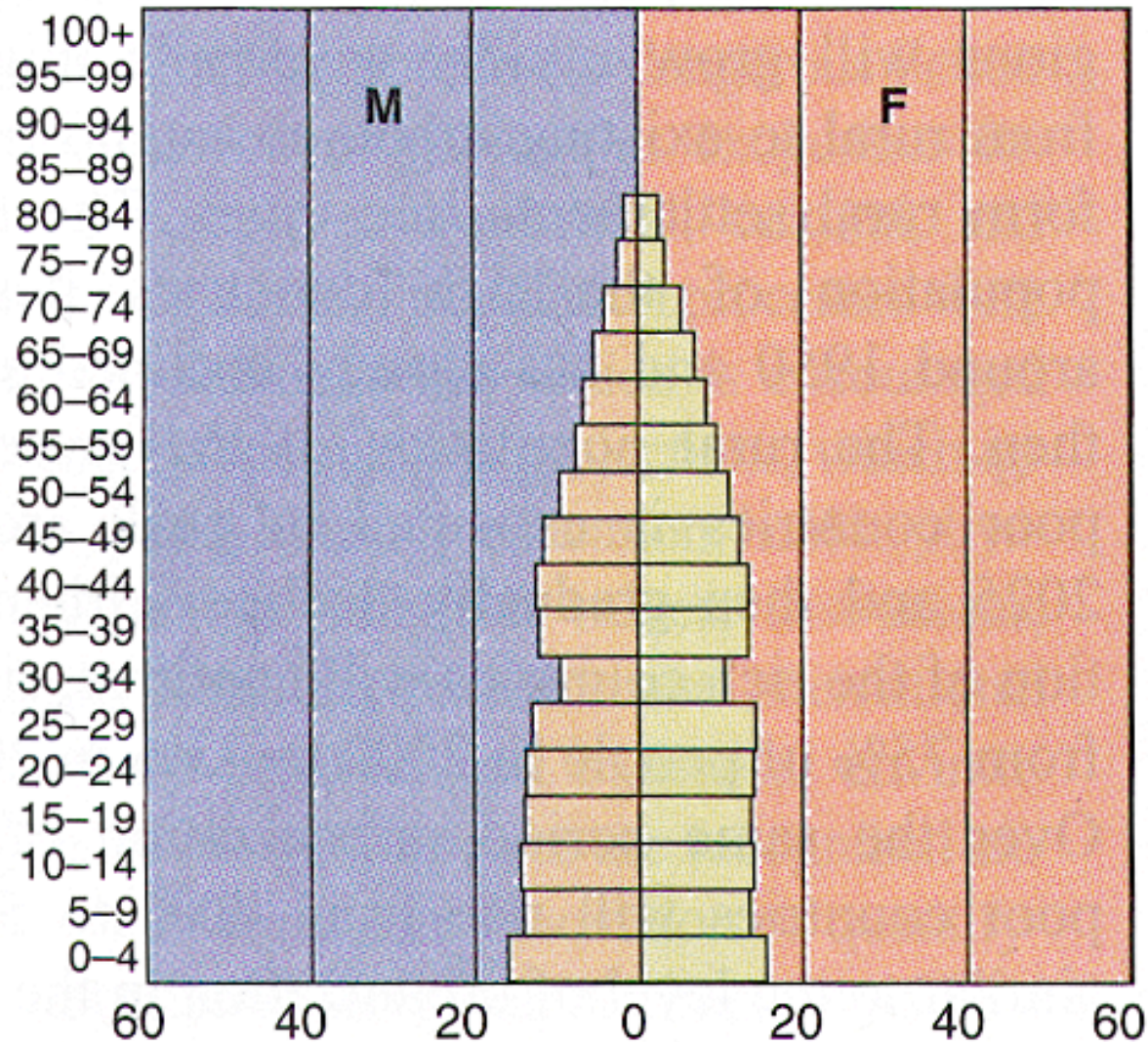
Big Trends for Robotics

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- Aging population
- Increased health costs
- Immigration backlash
- Globalization backlash
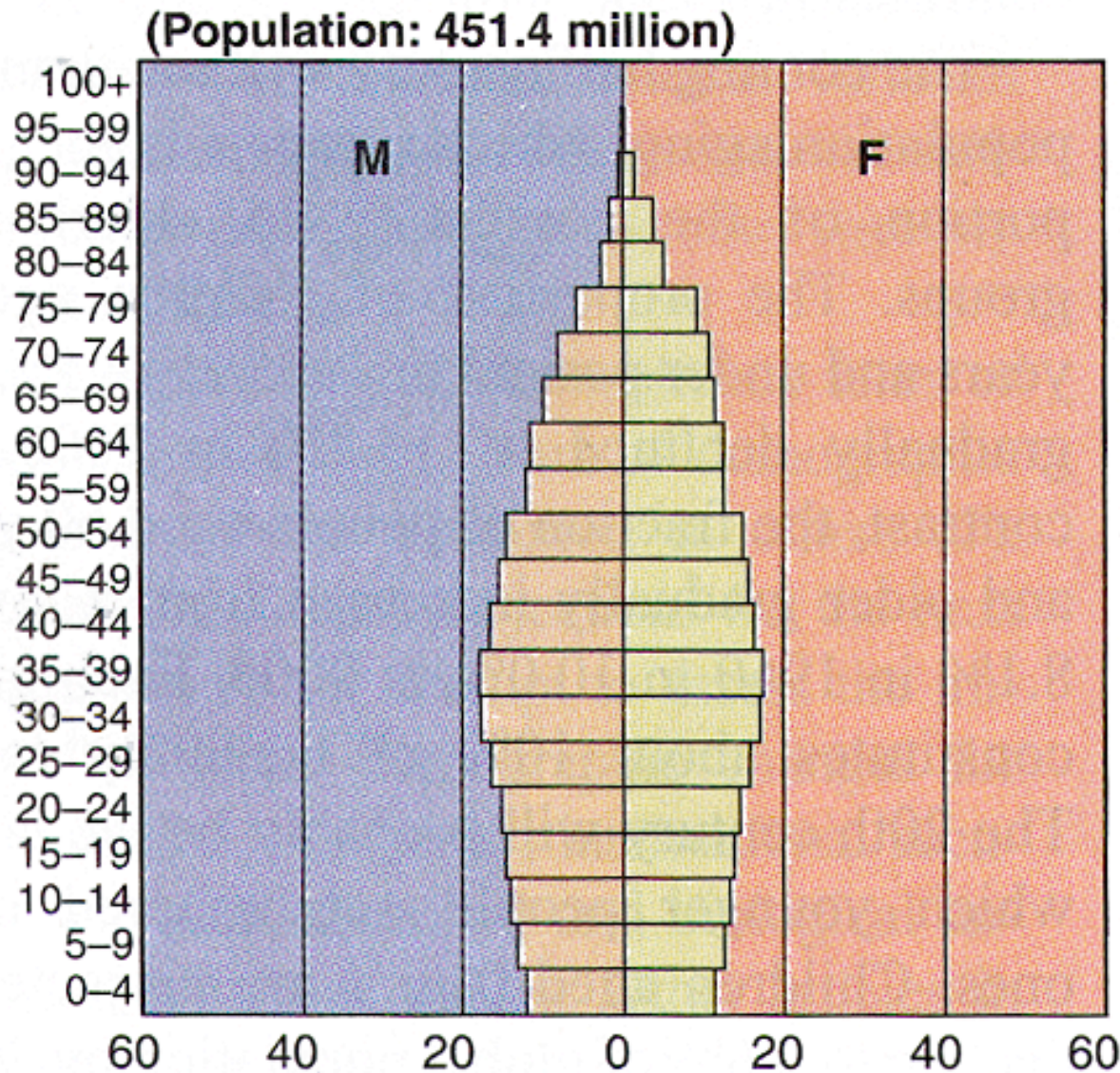- Future of transportation
- Carbon neutral energy

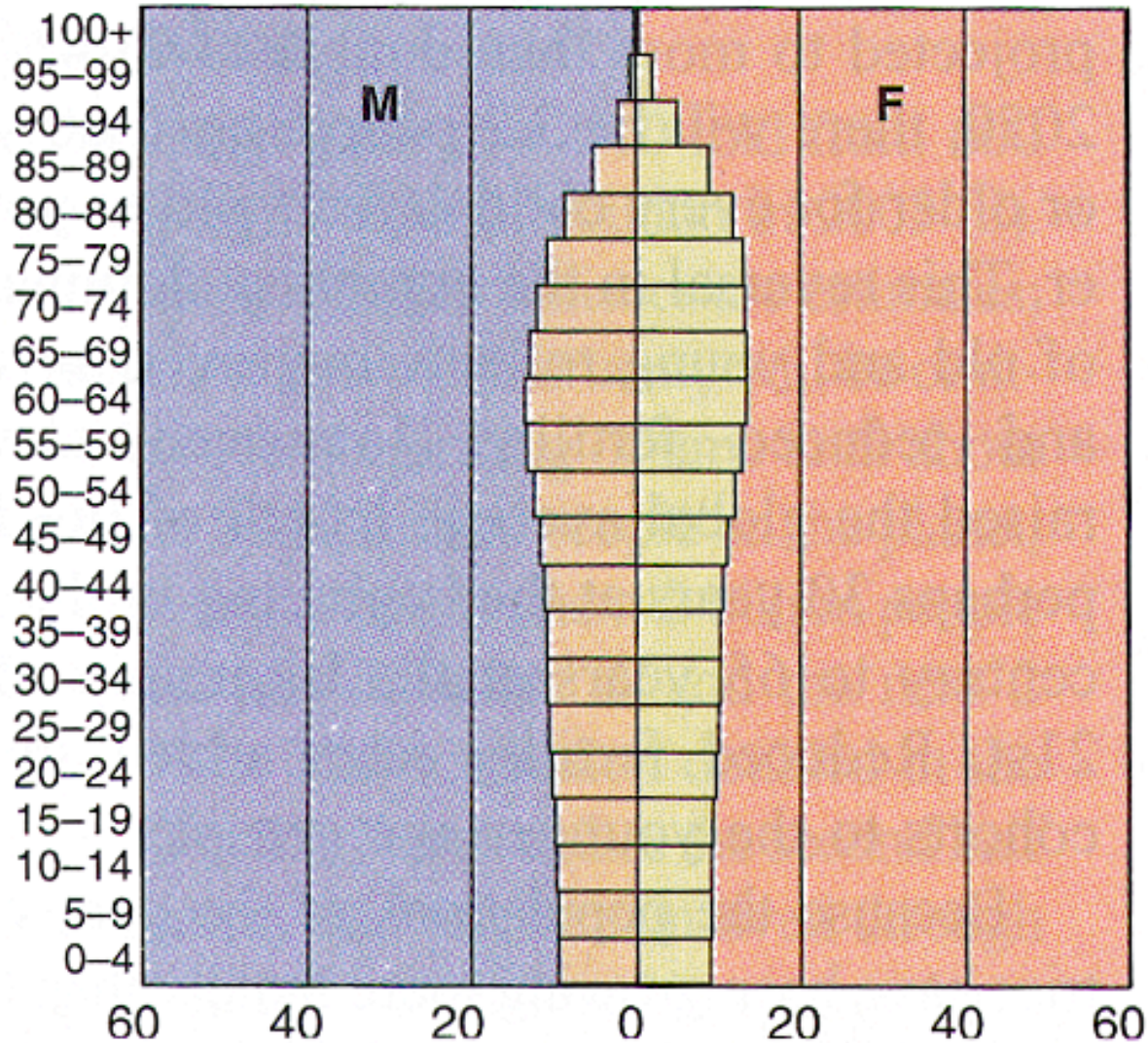# Europe - 1950

(Population: 349.8 million)

Europe - 2000

(Population: 451.4 million)
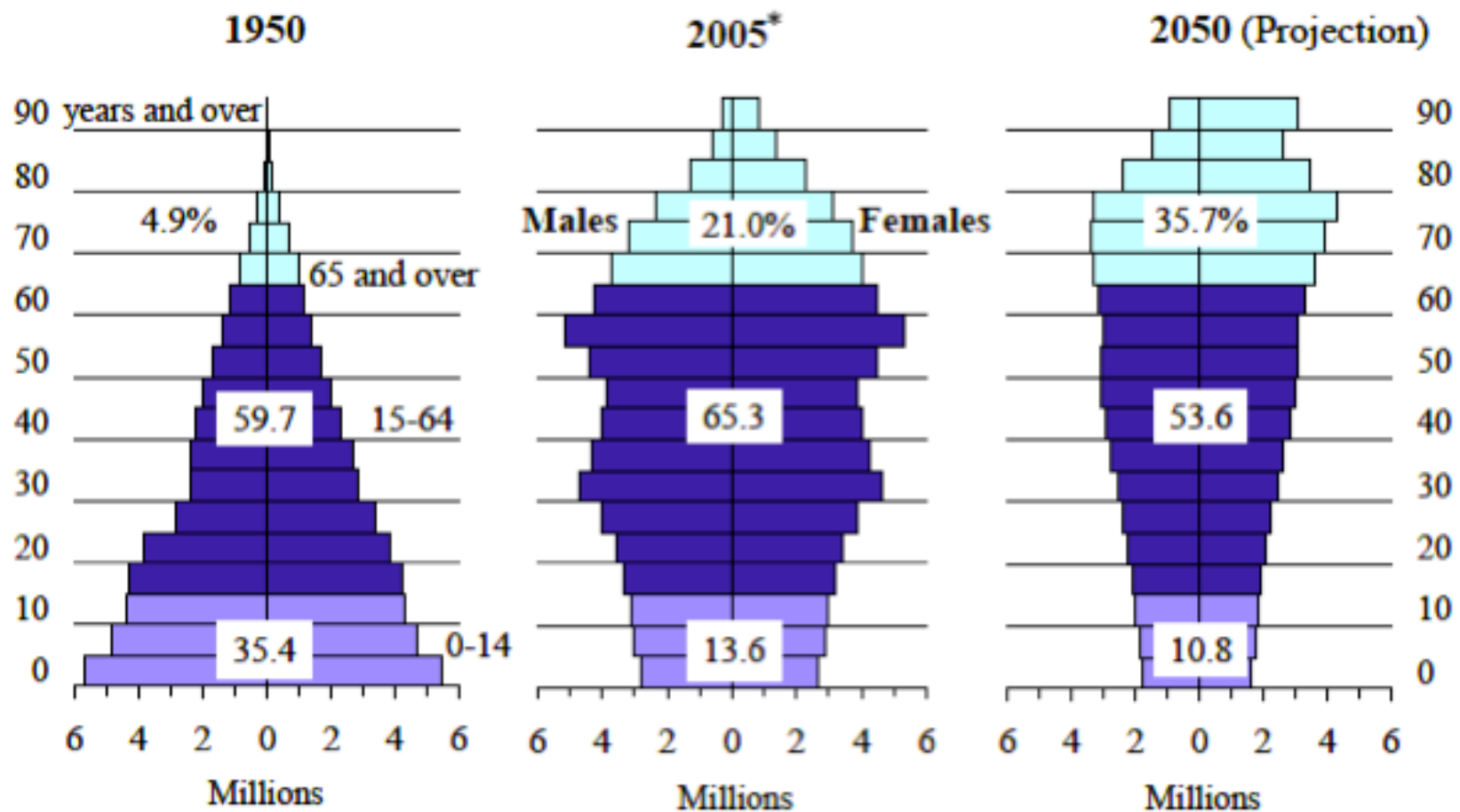
JE Cohen, Science 302, 1176 (2003)

Europe - 2050
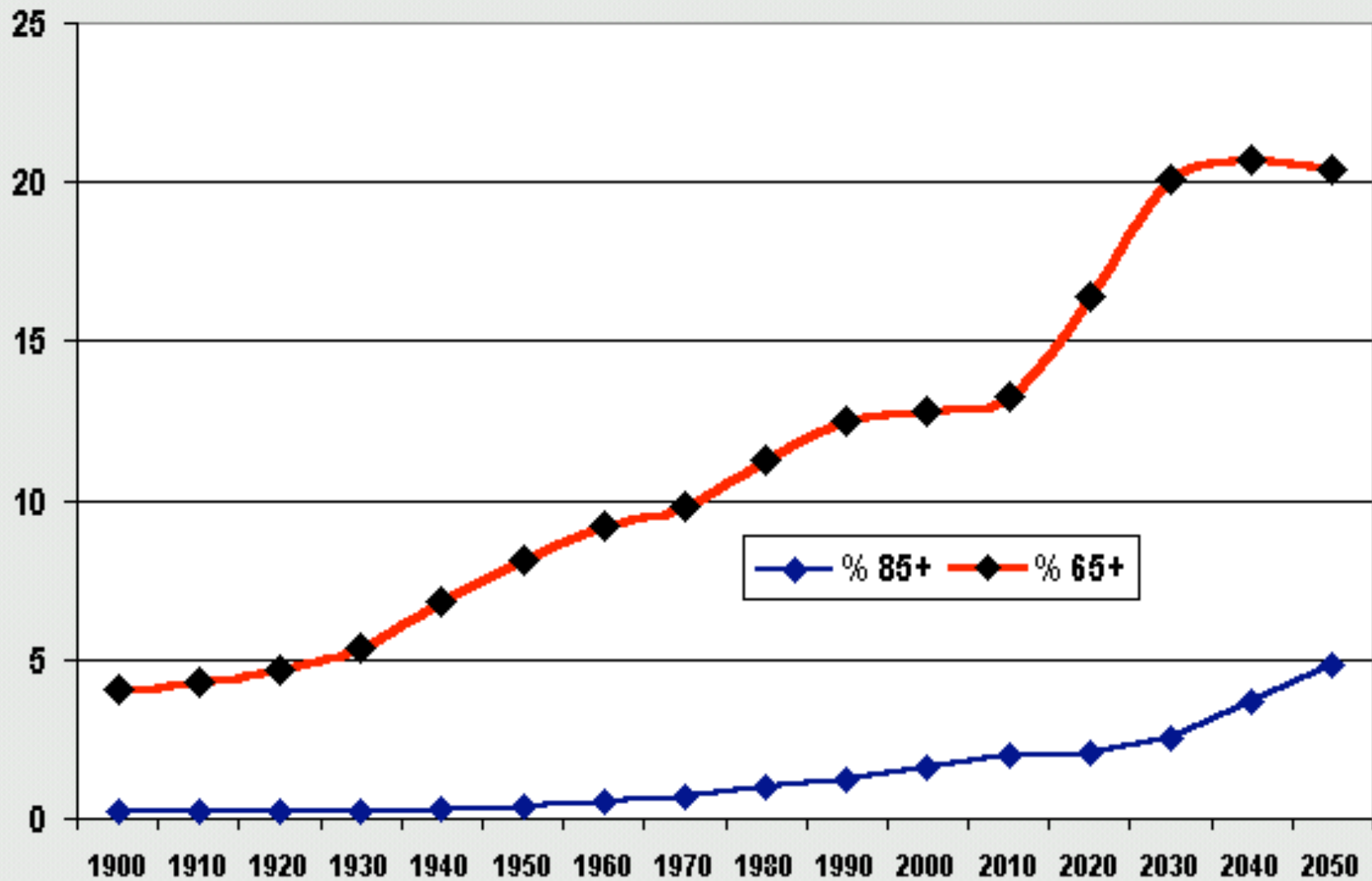

(Population: 401 million)
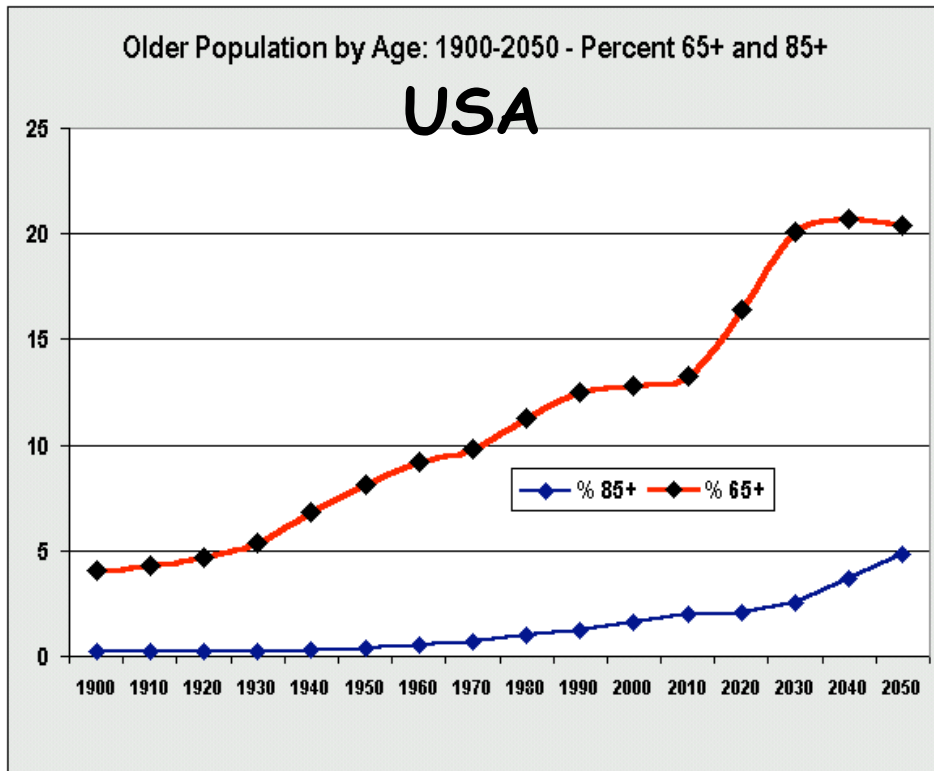
Japan: 1950 to 2050

Statistics Bureau, Japan Ministry of Health, Labor, and Welfare
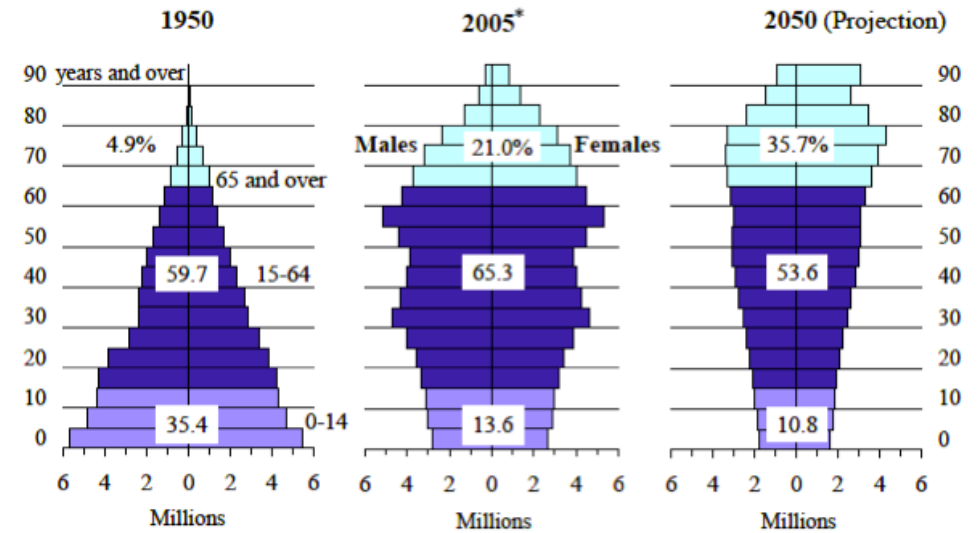
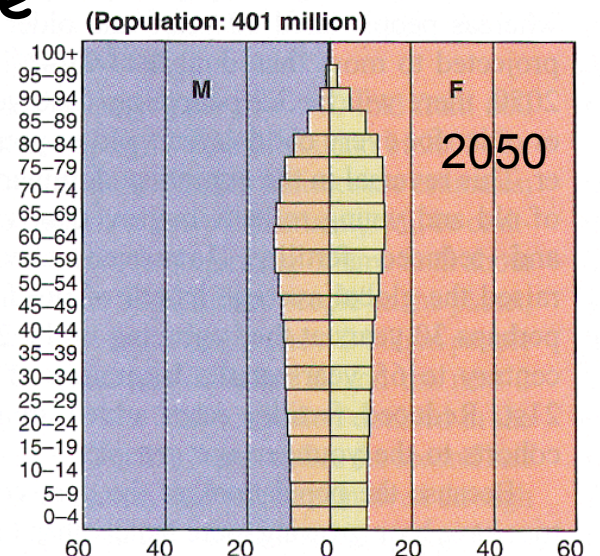Older Population by Age: 1900-2050 - Percent 65+ and 85+

USA

Older Population by Age: 1900-2050 - Percent 65+ and 85+

USA

Japan

Europe

1950 (Population: 349.8 million)
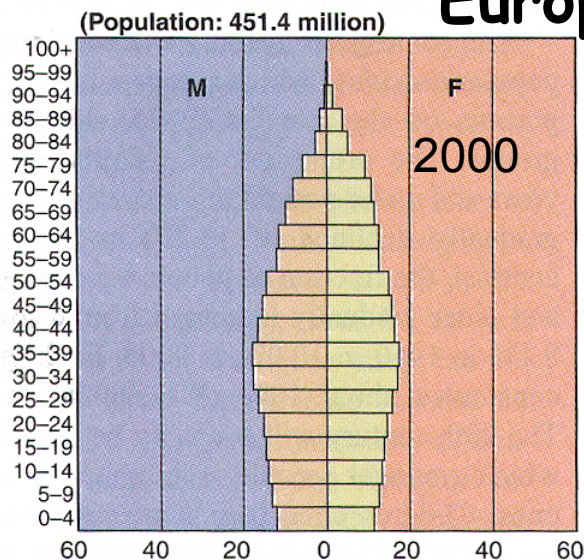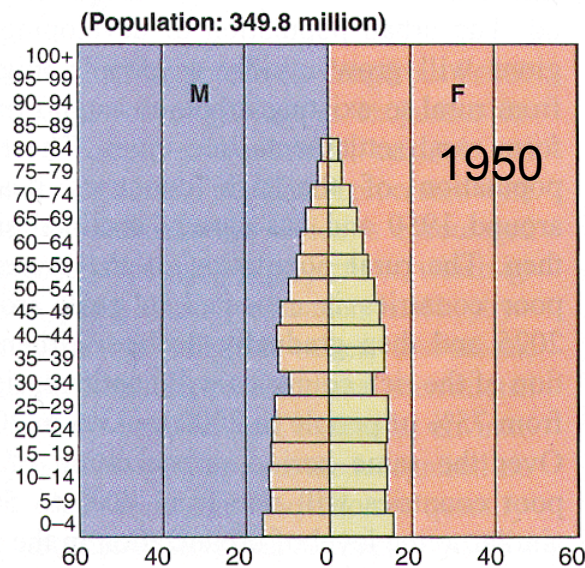
2000 (Population: 451.4 million)

2050 (Population: 401 million)

IDG News, Dec 6, 2007

At a Tokyo news conference held to unveil the two new robots, Toyota also showed its Robina robot, which made its first public appearance in the middle of this year. The Robina is designed for face-to-face communication with humans. In that role, the robot served as a guide at the Toyota Kaikan Exhibition Hall in Toyota City in August this year.

The robot can automatically navigate a route through obstacles and, by holding a pen in one hand and a piece of card in the other, sign its signature on the card.

Toyota is one of many Japanese companies actively investigating robotics and the areas that go hand-in-hand with the technology, such as artificial intelligence. While violin playing and autograph signing may appear to be nothing more than whimsical tricks they require a high level of mechanical and electrical control and are the kind of tasks that engineers need to perfect before they take the next step towards human assistance.

Japan's rapidly aging society is providing the push behind all these projects.

Immigration Backlash

- Both a legal and an illegal issue
- Some industries are suffering due to loss of illegal immigrants (e.g., OK, CO, CA)
- Some places are suffering due to legal immigrants getting too rich (e.g., lack of Polish workers in UK and Germany)

- Some work just has to take place in-situ, and not even immigrants want to work there

Robots to rule at Rio Tinto

Ben Woodhead | January 18, 2008

Font Size: A⁻ A⁺   Print Page: 🖨

RESOURCES giant Rio Tinto will replace humans with robots in its Western Australian mining operations over the next two years as it rolls out a fleet of automated vehicles including trucks, trains and drilling rigs.

Rio Tinto chief Tom Albanese wants the resources giant to be global leaders in fully integrated, automated operations

The work is part of Rio Tinto's 'mine of the future' program, which has been underway for close to a decade and aims to radically transform mining by automating processes throughout the supply chain.

"We're aiming to be the global leaders in fully integrated, automated operations," Rio Tinto chief executive Tom Albanese said today as the miner unveiled its plans for robotic mining over the next two years.

"It will allow for more efficient operations and directly confront the escalating costs associated with basing employees at remote sites, giving us a competitive advantage as an employer along the way."

A number of new technologies including autonomous drilling rigs, trucks and trains will be deployed in Rio Tinto's Iron Ore division in Western Australia's Pilbara region over the next two years.

The vehicles will be part of a two-year trial of autonomous technology and the company hopes to install robotic gear at other iron ore mines from 2010.

Globalization Backlash

- Worries about product quality when built in unregulated environments
- Cost of transportation
- Anger at perceived loss of jobs
- Worry about loss of US capability

- Can robots increase the productivity of US manual workers?

But, Also Need Research…

- Visual object recognition capabilities of a two year old child

- Language capabilities of a four year old child

- Manual dexterity of a six year old child

- Social sophistication of an eight year old child

Two examples from my students
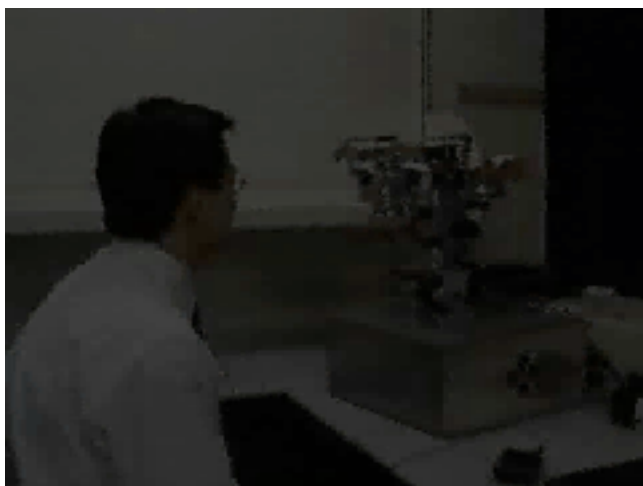
Kismet, by Cynthia Breazeal, 2000

Domo, by Aaron Edsinger, 2007

My Messages:

- A new class of robots just gotten here

- Defense robots are at the vanguard of a transformation of human society

- There are lots of technologies that are enablers

- There is going to be strong pull from many future user communities

Military Unmanned Ground Vehicles
International Development Activities

Nicholas S.J. Karvonides
Institute for Defense Analyses (IDA)
Alexandria, VA

NDIA Ground Robotics Capabilities Conference & Exhibition
San Antonio, TX

March 2008

1

Overview

- **Introduction**

- **NATO & International UGV R&D Activities**

- **NATO-US & International UGV Technology Standards**

- **NATO-EURON & European Robotic Trails (ELROB)**

- **EU-EDA & International UGV R&D Activities**

- **International Participation in DARPA Urban Challenge**

- **Conclusions**

Introduction

3

NATO & International UGV R&D Activities

NATO RTO R&D Activities

- Unmanned systems are prevalent in numerous NATO R&D activities as both the focus of R&D topics (platforms) or as a subset of other topics (ISR)

    -- However, attention to UAVs far outpace attention to UGVs

- Nonetheless, R&D efforts in both areas above provide insights into foreign military UGV capabilities & R&D activities while identifying key participants

- Background: NATO's Research & Technology Organization (RTO) promotes cooperative R&D & S&T exchanges among 26 nations & 38 partner countries

    -- Largest international collaborative body, 3,000 subject matter experts (SMEs)

- RTO operates by "organizing studies, workshops, symposia & other forums" through Working Groups (WGs) from RTO's 6 Technology Panels (TPs):

Applied Vehicles	Human Factors & Medicine	Information Systems
System Analysis	Systems Concepts & Integration	Sensors - Electronics

- RTO generally does not fund R&D (e.g. grants, contracts) nor does RTO typically initiate cooperative R&D ventures (e.g. CRADAs)

    -- RTO mostly supports (NATO-only) symposiums (50 - 100 SMEs) & joint analytic projects of small (~12 SMEs) study groups (SGs) -- (~45 SGs total)

NATO RTO UxV - UGV R&D

- A initial review of 6 NATO RTO TPs & quick scan of related TP SGs, show UxVs & related technologies were popular subjects & many aspects are addressed by numerous TPs

- Surprisingly, there does not exist an individual NATO RTO TP on UxVs in general or UGVs specifically

- UxVs & UGV TP activities seem more focused on new technology developments vs. expanded application of existing technology to broader warfighter capability needs (e.g. CONOPS, TTPs, DOTMLPF)

- Numerous UxVs & UGV R&D activities are currently underway or recently concluded among NATO's 6 TPs & various WGs

NATO RTO TP Research Task Groups (RTGs) on "Multi-Robot Systems & Military Applications"

- One (multi-phase) WG of particular note (2001 through December 2007) was the Information Systems TP's (IST) Research Task Groups (RTGs) on:

  [1] "Multi-Robot Systems in Military Domains" (IST-032 / RTG-014) &
  [2] "Military Applications For Multi-Robot Systems" (IST-058 / RTG-024)

  -- Maintained a long-term focus & emphasis on UGVs (vs. other UxVs)
  -- Undertook unique efforts (2004 - 2005) to forecast military UGV capability needs, warfighter requirements & UGV technology-industrial base capacity
  -- Related results where used to identifying near-term military capability "gaps" & "gaps" in future technology-industrial base capacity (2004 - 2008)
  -- Outcomes included the development of requirements analyses & notional technology roadmap as well as identification of UGV R&D investment priorities

- RTG activities concluded in December 2007 & a final report is due in 2008

NATO RTG UGV 2004-2008 Roadmap Exercise Needs, Requirements & Technology Gaps

Military Capability Needs	Military Requirements	Technology Gaps
Reconnaissance and surveillance for tactical support for forces on the ground including NBC	Communications (COMS): mobile, wireless ad-hoc, high ranges / rates, multipoint, QoS compliant, prioritize data, secure, network availability adjustable	COMS system should meet requirements but current tech does not support all requirements at same time
De-mining (tactical-post-conflict) clearing roads, fields (anti-tank / anti-personnel).	Platform: mobility, ruggedness, EMP shielded, low manning burden, modular concepts, greater standardization (power, connectors)	Platform: SOA power cells, efficient motor drive / power train, refined transition / suspension, lower mass / armored, lower workload, EMC hardening
Convoying, transport of goods	Sensing & World Modeling (S&WM): World modeling for navigation & mission execution, high on-board processing capacity & information	S&WM: multi-sensor suite fusion - more robust world view, obstacle avoidance, terrain modeling, UXO/OED & NBC sensors, environmental mapping, sensor fusion, object detect-recognition
Inspect vehicles and people for explosives and weapons at checkpoints.	Navigation & Mission Planning (N&MS): Mission planning, path planning and navigation; sensor information distribution and distributed behavior communication and coordination (e.g. JAUS)	MRS: multi robot interaction different-same tasks, collaborative tasks, autonomously divide a task, cooperative perception, autonomously manage-prioritize
Carry equipment for dismounted solider		
	Multi-Robot Systems (MRS): workload sharing, distributed sensing, cooperative-collaborative behavior, fully distributive / hierarchical control	N&MS: autonomous road following, mixed traffic, moving in tactical behavior, follow the leader
	Human Robot Interaction (HRI): Upgrade from continuous manual remote controlled to supervised autonomous	HRI: <50% workload simple terrain / <75% difficult terrain, execution plan in advance of maneuver, wearable interface, evaluate performance measures, improved ergonomics, common interface

NATO RTG Roadmap Exercise Observations

- Said to be the first effort of its kinds (likely regarding a multi-national military UGV "requirements development & technology roadmapping" initiative)

- Interesting note about importance of standards & reference to JAUS

- Nevertheless, self-assessed need for broader involvement of NATO military & warfighter inputs concerning UGV CONOPS, TTPs & DOTMLPHF issues

- No apparent references found about counter-IED needs (vs. possibly more conventional de-mining applications) or counter-sniper / counter-mortar

- No needs identified specific to the weaponization of UGVs (possible ethical concern) & limited reference to target acquisition for precision weapons

- No reference found concerning application of lessons-learned relative to UGVs & OEF / OIF or those specific to urban reconnaissance-surveillance needs

- Finally, detailed mention was observed concerning opportunities for UGV experimentation & simulation of future military UGV CONOPS & TTPs

- Overall, this RTG exercise seems to be an impressive & novel effort between NATO militaries, defense firms & research organizations

NATO RTO RTG
Recommendations & Developments (2004-2008)

- Recommendation for multi-nation military UGV R&D investment campaign & increased warfighter customer & requirements community participation

- "A problem is that military users are interested in UGVs but have to consolidate funding" & "current research is ad hoc & no real user pull"

- Recommendation for a "European version of DARPA" & "lobbying for funding & defense research demands"
  -- cooperation should come from military users (war fighters) from various countries" (2005)

- Recently revealed (late 2007) the European Defense Agency (EDA), is taking on role to advance EU military UGV R&D & investment (next section)
  - However, US-firms & DOD are generally restricted from EDA participation

- Other RTG activities include close collaboration w/ European Robotics Network (EURON) illustrating value of commercial & academic innovation

- RTG instrumental in the creation of the newly established (2006) European Robotic Trails (ELROB) to assess EU's UGV state-of-the-art (next section)

- NATO said to be forming new RTG to address deconflicting & harmonization of interoperability standards (e.g. JAUS vs. NATO STANAG) (next section)

Additional NATO RTO UGV-UxV R&D Activities

Information on additional NATO RTO UGV-UxV activities are listed below which provide useful insights into other international military UGV-UxV current capabilities, near-term R&D activities & key participants:

RTO-MP-AVT-146: Platform Innovations & System Integration Unmanned Air, Land & Sea Vehicles: RTO Applied Vehicle Technology Panel (AVT) Symposium, Florence, Italy, May 2007

RTO-MP-HFM-135: Human Factors Uninhabited Military Vehicles as Force Multipliers: RTO Human Factors & Medicine Panel (HFM) Symposium, Biarritz, France, October 2006

RTO-TR-HFM-078: Uninhabited Military Vehicles: Human Factors Issues in Augmenting Force (2002 - 2006): RTO Human Factors & Medicine Panel (HFM) TG HFM-078/TG-017

SCI-144: Integration of Systems with Varying Levels of Autonomy (2004 – 2007)

NATO-US & International UGV
Technology Standards

International Standards & Harmonizing UxV Interoperability

- Further UGV technology development & greater utilization face challenges:
  - International barriers to accelerating innovation & faster technology transition
  - Impediments to broader systems integration & increased interoperability

- With rapidly changing technology, increasing globalization of manufacturing supply chains & internationally distributive product development

  ....internationally adopted standards are crucial to commercial, defense & dual-use industrial base integration & increased competitiveness

- Dynamic & unpredictable national security & homeland defense scenarios

  ....require fast-forming coalitions (locally & abroad), responsive net-centric enabled systems & transformational military capabilities

  ...all are dependant on interoperability to communicate, coordinate & collaborate

- Interoperability standards also support key UGV acquisition goals:
  - Lower life cycle costs, faster development time & quicker product integration
  - Open standards further support common interface for technology insertion
  - Enable expansion of existing systems w/ additional (spiral-on) capabilities 13

DOD / SAE AS-4 "JAUS" Standard

- To facilitate greater interoperability of future US unmanned systems ...new standards were developed by DOD & industry

- DOD developed the Joint Architecture for Unmanned Systems (JAUS) as the interoperability standard for UGVs (Army in 1994, OSD in 2002)

  - Primarily for communications & data handling for UGV command & control

  - Applicable at the system level as well as subsystem & component level

  - Consistent with US Government (USG) policy DOD transitioned JAUS to the private sector & the international Society of Automotive Engineers (SAE AS-4)

  - DOD UGVs utilize JAUS as do Army UAVs & Unattended Ground Systems (UGS) for Future Combat System (FCS)

  - As UxVs proliferate with state-local authorities, so will the use of JAUS standard

  - For example, National Bomb Squad Commanders Advisory Board (NBSCAB) requires EOD robots to be JAUS-compliment when purchased w/ USG funds

NATO "STANAG 4586" Standard

- NATO established Standardization Agreement (STANAG) 4586 in 1996

- Following a NATO Industrial Advisory Group (NIAG) study on tactical UAV system interoperability

- 4586 supports a standard interface of the Unmanned Control Systems (UCS) for NATO UAV interoperability (established 2002)

- The goal is to support NATO "multinational UAV interoperability"

- Specific objective is "to provide a standard for three key interfaces"
    Data Link Interface (DLI)
    Command and Control Interface (CCI)
    Human Control Interface (HCI)

- Applicable at the system level vs. the subsystem & component level

SAE AS-4 (DOD) JAUS VS. NATO STANAG 4586

JAUS & STANAG evolved to the most common standards for unmanned systems

<u>However, JAUS & STANAG are not fully interoperable</u>:

- Among full UxV spectrum (all domains) as well as unmanned-manned systems

- Across DOD Services, NATO & coalition allies as well as state-local authorities

  - Example: NATO, US NAVY & AF UAVs use STANAG (plus Navy USVs & UUVs) which raises question of interoperability of UGVs in littoral & riverene environs

- In addition, DOD-NATO interoperability challenges exist w/ UAVs & STANAG

- Another twist: USG policy support of open industry standards & the goal of USG standards to "promote efficiency & economic competition"

  - Example, STANAG 4586 is NATO "UNCLASSIFIED" (but NATO-only) restricting access to many global suppliers & non-traditional innovators from non-NATO countries such as robotics industry leaders in Japan & South Korea

  - Could similarly conflict with civilian state-local authorities & their supplier base relative to USG technology transfer authorities & impeded interoperability of related commercial dual-use systems with military systems

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Future JAUS VS. STANAG Questions-Issues

- Unknown extent of the future use of JAUS vs. STANAG by foreign military UGVs vs. foreign law enforcement UGVs given they often share common equipment

- Foreign UGV manufacturers may often use proprietary standards
  - Example, U.K.-based, QinetiQ's use of Common Interface Protocol (CIP)

- Foreign *"home grown"* standards possibly common as UGVs traditionally used locally in stand alone scenarios vs. systems-of-systems of international coalitions

- This will change as future teams of UxVs (& manned systems) evolve globally

- It may be likely that foreign UGV companies will develop future UGVs around JAUS in to order compete for export opportunities within the world's largest JAUS-compliant defense & homeland security market

- Will US firms selling JAUS systems to DOD proliferate JAUS internationally through exports given US lead in military UGVs & defense exports overall

- With the flood of US & foreign STANAG-compliant UAVs (& quarter century lead & growing integration w/ other systems) ....is STANAG positioned for growth

Efforts to Harmonize International Standards

- According to DOD's new Unmanned Systems Roadmap: US is engaged in working with nearly a dozen NATO countries on improving STANAG UAV interoperability

- Although no formal mechanism is in place between DOD and NATO on working through like kinds of interoperability challenges with JAUS -- current efforts between DOD and NATO on improving UAV interoperability with could serve as an effective entrée to harmonize JAUS & STANAG

- Recent news of a new effort getting underway in Europe with the possible creation of a NATO RTO Working Group on harmonizing standards across multiple UxV domains as well as between unmanned & manned systems

- Growing momentum exist for DOD & NATO to collaborate on harmonizing interoperability standards for UGVs as well as the full spectrum of UxVs across all domains

NATO-EURON & European Robotic Trails (ELROB)

European Land-Robot Trial (ELROB)

- Annual field robotic demonstration of state-of-the-art (SOA) UGV capabilities for military & related civilian applications (est. 2006 & 2007)
  - annually alternating between military (2006) & civilian applications (2007)
  - sponsored by NATO RTG & European Robotics Network (EURON) & hosted by German MOD
  - goal is to stimulate European UGV innovation & expand industrial base
    …. by encouraging UGV cluster development & multi-country collaboration as well as leveraging R&D investment & increasing market awareness & demand

- ELROB first hosted 20 European teams from 5 countries in Germany (2006)
  - 600 spectators from 19 countries
  - military scenarios in both urban & non-urban environments
  - focused on vehicle mobility & reconnaissance-surveillance applications

- ELROB is considered a one-of-kind window into Europe's SOA UGV capabilities

- ELROB excludes direct US firm participation although EU-based US subsidiaries (or potential EU teaming possibilities) may possibly enable US involvement
  -- non-EU observers are welcomed to attend

EU-EDA & International UGV R&D Activities

European Defense Agency (EDA) Multi-Government Military UGV R&D Initiatives

- EDA created in mid-2004 as an agency of the European Union (EU) & governed by Ministries of Defense (MODs) of 26 participating EU states

- Objective: Increase shared-use of military equipment between EU member nations & support of multi-country defense industrial base collaboration & R&D partnerships

- Goal: Increase cost-effectiveness & affordability of equipping EU armed forces while strengthening the international competitiveness of EU's defense technology-industrial base

- First of 4 EDA initiatives in 2005 included development of an Armored Fighting Vehicle (AFV) Roadmap & 2 associated feasibility studies (Networked Enabled AFVs & Unmanned Ground Tactical Vehicles)

- Feasibility studies resulted in recent launch of 3 military UGV R&D programs in late 2007 & subsequent start of a 4th UGV program in December 2007

- Combined level-of-effort (LOE) of 4 UGV R&D programs initially ~$30M USD

- Non-European country MODs & companies are generally excluded from directly participating in EDA R&D programs

EDA Military UGV R&D Program 1: "Semi Autonomous UGV" (SAM)

- Scope to included identification of:
  - Existing, state-of-the-art (SOA) UGV systems & subsystem technology & industrial base capabilities of EDA countries
  - UGV military capability gaps (primarily reconnaissance missions)
  - Corresponding UGV & subsystem R&D development projects
  - Latter will be used to formulate follow on UGV integrated development teams

- Applications aimed at UGV missions for patrolling, counter-IED & CBRN

- EDA German MOD Leads Program

  Industry Participation: Germany (Rheinmetall and Diehl BGT), Spain, France (Thales and Canberra Eurisys), Italy (Galileo Avionica) & UK (BAE Air Systems)

- Level of Effort (LOE): 4 years with 10M - 12M Euros (up to ~$17.5M USD)

EDA Military UGV R&D Program 2: "Use Robotics" (UGV)

- Program scope to include:

  - Develop generic "demonstration system" for UGV convoy applications

  - Likely intended platform(s) will be an existing "manned" vehicles

  - R&D program aim is to develop a UGV "modular conversion kit"

  - Various vehicles targeted in "several tons" class & upto 10 to 12 tons

  - Vehicles to operate in different environments & road conditions

  - Allow remote operator to supervise mission & take control when needed

- EDA Italian MOD Leads Program

  Industry Participation: Italy (CIO Consorzio Iveco - Oto Melara), Germany (Rheinmetall and Diehl), Greece (Hellenic Aerospace Industry), Spain (Espelsa), Finland (Patria Group), France (Thales), Poland (Edisoft), Portugal & (possibly), Cyprus

- LOE: 4 year, phase one 9 mo., 1.2M Euros - 1.4M Euros (~$2.07M USD)

- Subsequent R&D funding phase(s) to be determined after UGV MOD phase one requirements identified, industrial base capabilities assessed & gaps determine

EDA Military UGV R&D Program 3: "Networked Multi Robot System"

- Focus: "open architecture", software tool development effort

- Goal: Simulating (i.e. "test bed") networked, multi-robot ("collaboration") UxV systems in ground, air & sea domains

- Application area: C4I

- EDA German MOD Leads Program

  Industry Participation: Germany (Diehl BGT Defense and FGAN research center), Belgium (Royal Military Academy), Italy (Oto Melara of Finmeccanica), and Spain (Sener)

- LOE: 36 month, with $4.5M Euro (~$6.57M USD)

EDA Military UGV R&D Program 4:
"Generic Urban Area Robotized Detection CBRNE Devices"
(GUARDED)

- Demonstrating (presumably developing) remote controlled, mobile platform for detecting / sensing CBRNE devices (materials)

- Key aspects: High detection confidence & at a safe (stand-off) distance

- Sensor technologies of interest: Ground Penetrating Radar, Proton Transfer Reaction & Mass Spectrometry (through-wall & buried target detection)

- GUARDED is 1 of 3 new R&D Joint Investment Programs for EDA's Force Protection (JIP-FP) initiative

- JIP-FP is a new EDA initiative funded with 55M Euros (~$80.3M USD)

- EDA MOD Program Lead Unknown

  Industry participation: France (ECA & DDSC), Austria (Ion), Slovenia (IPS) & Finland (ENV)

- LOE: 3 years with 3.5M Euros (~$5.1M USD)

International Participation in DARPA Urban Challenge

Foreign Country Participation in DARPA's 2007 Urban Challenge

- Significant international involvement from foreign universities, industry & associated technology organizations:
  - 3 to 4 countries registered 6 to 7 teams including:
  - 1 team from Canada, 1 from France & 4 teams from Germany
  - 1 US team, AvantGaurd, (Israeli Elbit subsidiary) -- semi-finalist

- 2 German teams selected as semi-finalists:
  - Team Berlin (led by Frey University Berlin)
  - Team-LUX (industry led by Ibeo & STICK)

- 2 German teams selected as finalists:
  - Team AnnieWAY (Collaborative Research Center Cognitive Automobiles)
  - Team CarOLO (five institute collaboration of the Braunschweig University)

Foreign Technology Contributors to DARPA's 2007 Urban Challenge

- Germany S&T & industrial base also a major contributor to other teams:
  - Volkswagen of America's Electronics Research Laboratory (Palo Alto) partnered with Stanford University's Racing Team
  - Ibeo & SICK laser scanner navigation devices outfitted 53 out of 89 teams

- Italy plays key role in equipping US Team Oshkosh (formerly TerraMax):
  - Leading edge, stereo visioning system technology developed by Italy's University of Parma's VisLab
  - VisLab has a history of R&D collaborations with US industry on a number of DOD military UGV projects

- Additional international participation including: Australia, Austria, China, New Zealand & Mexico

Conclusions

Evaluation of Man-Portable Robots for Urban Missions

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Acknowledgement

- Joint effort with Major Carl Lundberg, I1

- Direct collaboration with the Royal Swedish Regiment (I1)

  - Includes the Swedish international infantry unit

- Sponsored by the Swedish Defense Materials Administration

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& Intelligent Machines

Urban Assistance to Soldiers

- Urban intervention is stressful!

- Urban missions typically carries the most casualties

- There are well defined strategies for urban operations

- Clear that robots may be of significant value for such operations

- EU Battle Group 08? Should robots be included?

Task Motivation

- Entry into buildings is stressful

- A need to generate situation awareness

- Detection of key entities in an area

- Early reconnaissance

Objective of study

- A number of events has indicated the value of use of robots

- What are the challenges?

- Where can robots be used effectively?

- What are the main limitations?

Focus of study

- Embedding of man-portable robots into a group of soldiers for urban search and clearance

- Use of PackBot Scout systems from iRobot

- Changes in user interface

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& Intelligent Machines

User Interfaces

Interface example

What are user issues?

- How does the strategy change with a robot?

- What are the requirements for communication?

- Is the cost / benefit acceptable?

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& Intelligent Machines

Doctrine is well defined

How well do robots perform?

- Tested with Royal Swedish Regiment (~200 soldiers that are specialists in Urban interventions) over a periods of 12 months (2005-06, 2006-07, 2007-08) in total close to 600 soldiers

Missions

- Mapping of environments

- Search for objects

- Inspection

Evaluation Strategy

- Start
  - Questionnaire to all soldiers in regiment
    - Is this useful, applications, usability, limitations, ... 34 questions in total
  - Training in use ("operator school")
- Through-out evaluation period
  - Revision of strategy/doctrine
- By completion
  - De-brief of all and new questionnaire

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& Intelligent Machines

Analysis of Strategy

- Revision of group strategy
  - A robot is not just another sensor
- Strategy is highly task dependent
  - Clearance of a house is different from search, inspection, ...
- Careful analysis took 3+ iterations
- The problem is highly interdisciplinary!
  - Anthropology, CS, Human factors, ...
- The gain can be substantial

Lessons

- At start 30% thought robot would be useful

- By end 100% considered robot invaluable

- The strategy for a group must be revised

    - Adding a robot is not a trivial problem

- Different actors have different requirements

- Interfaces must be <u>carefully</u> designed

- An operator guard is needed - s/he is easily "lost" / cognitively overloaded!

HCI Lessons

- Situation awareness requires mapping

- Pure tele-operation challenges perception

- Simple things such as "snap" makes sense

- Semi-autonomy essential to relieve operator

- End user involvement is crucial

  - Do not leave it to engineers!

- Our children have better HW than our soldiers

Robotics@GT
& Intelligent Machines

Overall Lessons

- Early end-user involvement is crucial

- Long-term studies are required to generate credible results

- Essential to consider end-to-end process

- Careful evaluation is time consuming

Summary

- Small UGV systems can offer effective support

- Integration with unit must be carefully considered

- The design of user interfaces is not really there

- Long term evaluation is essential to understand results

- There are many issues to consider
  - Operations, Training, Logistics, ...

Ground Robotics and the Joint Warfighter

2008 NDIA Ground Robotics Capabilities Conference

4 March 2008

CDR Peter A. Young

Joint Staff, J8

Science and Technology Coordinator

Joint Staff Role in Ground Robotics

- **The "Voice of the Warfighter"**

  - **Consolidate needs of the COCOMs (IPLs) into JROC validated Capability Gaps (annually)**

  - **JUONs (continuously updated)**

BOTTOM LINE:

Ensure the Joint Warfighter has the required capabilities to execute the assigned mission in a resource constrained environment…

JCIDS Update

- **Senior Warfighters' Forums (SWarFs)**

- **Increased focus on cross-cutting Issues**

- **JCA Rebaseline**
  - **Nine Tier 1 JCAs**
  - **Two new FCBs:**
    - **Building Partnerships**
    - **Corporate Management**
  - **JT and FM FCBs combined into Force Support FCB**

- **2008 Gap Assessment**
  - **Validated by JROC on 28 Feb 08**
  - **No JROC endorsed prioritization**

- **Hub Trip for final coordination – this week**

Joint Staff Contributions to Ground Robotics

- **In 2007, the Joint Staff provided warfighter-need focus for Joint Ground Robotics Enterprise (JGRE) investments**

  - **Aligned Joint Ground Robotics proposals/projects with JCAs**

  - **Analyzed each proposal/project against validated warfighter gaps and current JUONS**

- **Ground Robotics address current warfighter needs:**

  - **Three "technologically challenged" JUONS are related to IED detection and defeat**

  - **From MG William Troy (Vice Director J8) at the 2008 Science and Technology Strategic Overview:**

"Robotics hold the key to providing the same or improved capabilities while keeping Soldiers and Marines out of harm's way."

A new effort…

- **THE PROBLEM:**
  - **Many IPLs have underlying S&T challenges and/or solutions that are not explicitly stated in the IPL submission (5x8)**
  - **Potential for overlooked S&T efforts due to missed ties to capability gaps**

- **THE SOLUTION:**
  - **COCOM Science Advisors are submitting underlying S&T challenges/needs from IPL submissions (later tied to validated gaps)**

- **THE BENEFIT:**
  - **Better inform S&T related funding decisions DoD-wide using the underlying S&T focus along with JROC validated gaps**
  - **Working with J-8 (JCD) and COCOMs to integrate this into next year's IPL/Gap assessment process**

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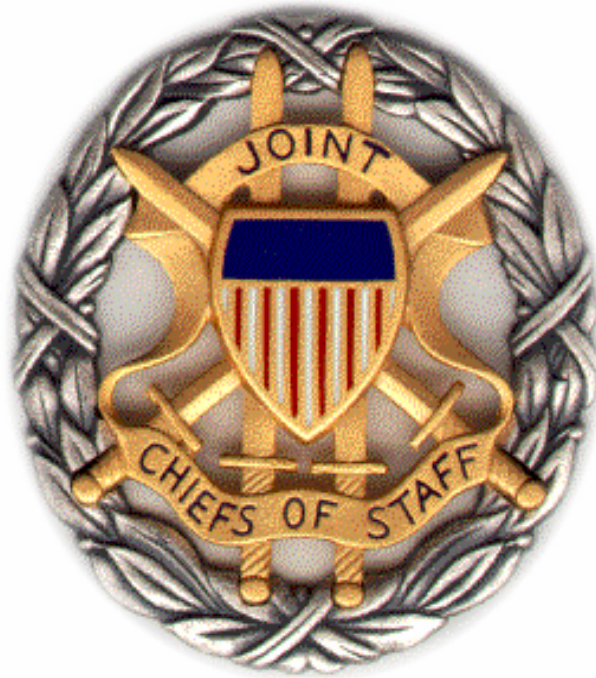
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CROSSING THE CHASM

High-Tech Marketing Illusion

The Revised Technology Adoption Life Cycle

Innovators — Early Adopters — Early Majority — Late Majority — Laggards
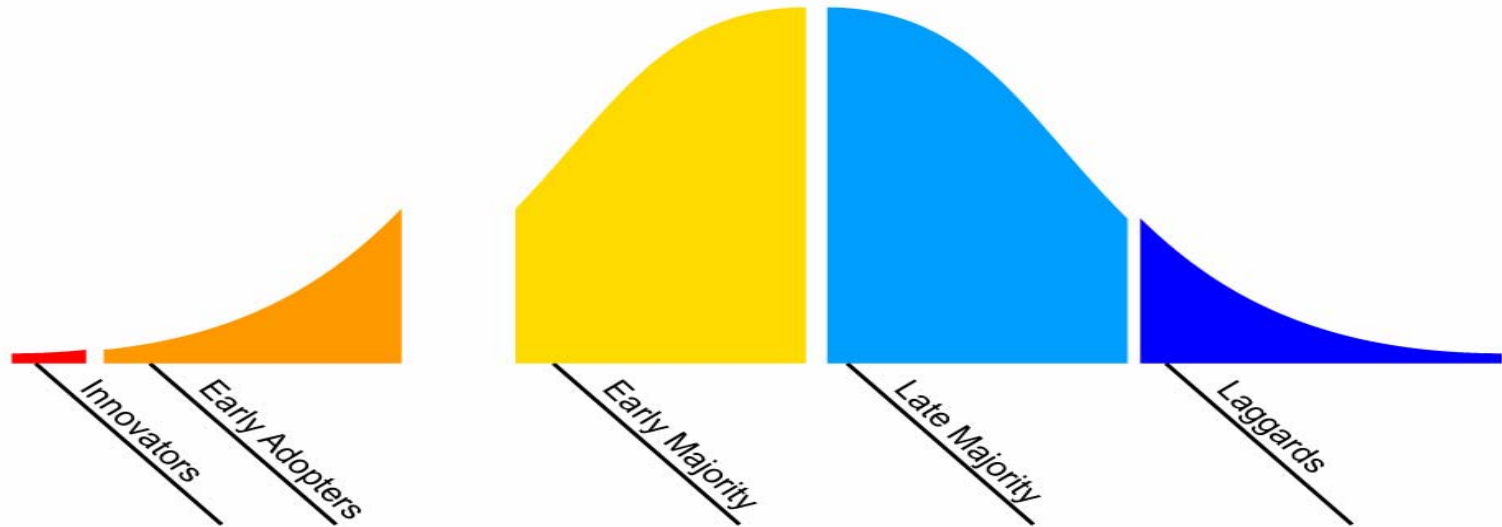
"Crossing the Chasm" by G. Moore, Harper Business Essentials

Soldiers will find more missions for robots than expected

2008 Ground Robotics Capabilities Conference

The State of the Enterprise

"…with the change of circumstances, institutions must advance also to keep pace with the times." *T. Jefferson*

Mrs. Ellen M. Purdy
Enterprise Director, Joint Ground Robotics
OUSD(ATL)/PSA,LW&M
ellen.purdy@osd.mil
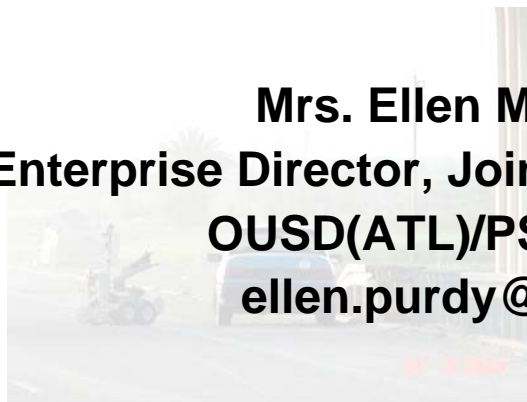
Agenda

- Recap from Last Year's Conference
- Current Efforts
- Top 5 Initiatives
- Conclusion

Recap from Last Year's Conference

- **Technology Transfer**
  - Warfighter Experiments

- **Unmanned Aerial Systems Lessons Learned**
  - User Feedback
  - Up front and early with Other Government Agencies

- **Setting the Azimuth**
  - Technology Advisory Board
  - O-6 Council
  - Senior Steering Group

Automated Perimeter Security (APS)

Purpose

- To develop automated technologies to augment the security force mission.

- Is an automated system of robotic platforms providing perimeter security to vital installations.

- Integrates robotic ground, air, and sea systems into a seamless network with existing USAF security system architectures.

Progress to Date

- Conducted successful experiments at Kirtland Underground Munitions Security facility and Eglin AFB.

- Demonstrated the adaptability and usefulness of system in a relevant environment.

- Integrated systems with Force Protection Joint Exercise participants.

Computer Aided Manipulation (CARMAN)

Purpose

• Assess the potential of existing automation technologies to enhance the military utility of robotic manipulator systems of fielded EOD solutions with emphasis on Improvised Explosive Device (IED) disposal and retrieval.

Progress to Date

• Enhanced manipulator automation by reducing time for repetitive tasks.

• Algorithms and methodologies for increased precision of manipulator control and increased ease of operation.

– e.g., converting 2-D location to 3-D location relative to system

Robotic UXO Technologies

Progress to Date

• 2nd generation robotics control system developed.

• Moving toward
  – automated driving behaviors - waypoint and pattern driving using GPS/INS guidance and automated and positive position control of the flail device.

  – a joint use system.

Purpose

• Provides an interim capability to accelerate the integration of advanced robotics and the mine-clearing platform to facilitate full operational capability.

Convoy Active Safety Technologies (CAST)

- **Perception and planning for safe maneuver among people and other vehicles; active safety systems for collision detection and avoidance**

- **Integration of unmanned systems within the network**

- **Enhanced tele-operation**

- **Way point navigation**

- **Affordability: cost of future systems using projected technology**

- **System robustness**

Top 5 Initiatives

- Integrated Unmanned Systems Roadmap
- Ground Robotics Consortium
- War Fighter Experimentation
- Test Implications
- Robotics Acquisition Standards and Policy

Integrated Roadmap

- **The Unmanned Systems Integrated Roadmap…**

  … is a master plan

  … describes the intended future state of the Unmanned Systems Product Line Portfolios

  … and the actions to be undertaken to achieve that future state.

- **Will account for Strengths & Opportunities; Challenges & Risks; Capabilities Matching; Responding to Plan, Concerns, Issues**

- **The Roadmap will serve to inform future decision making associated with the management of the Unmanned System Portfolios as they provide needed capabilities to the joint Warfighter.**

Ground Robotics Enterprise

Joint Ground Robotics Enterprise

- OUSD(AT&L) PSA/LW&M
- Department of the Army
- Department of the Navy
- Department of the Air Force
- Defense Treat Reduction Agency
- J8
- Other Agencies and Departments

Section 845 Other Transaction

Ground Robotics Consortium

?
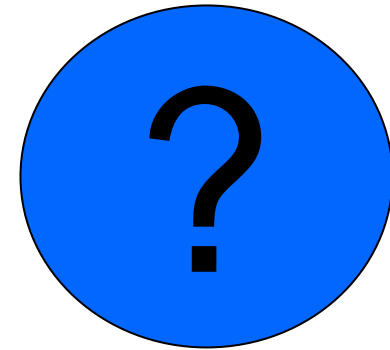
- Defense Contractors
- Small Businesses
- Academic Institutions
- Non-Profit Organizations
- Not-for-Profits Organizations

DoD and GRC … Partnering to Leverage Capabilities and Investment

10
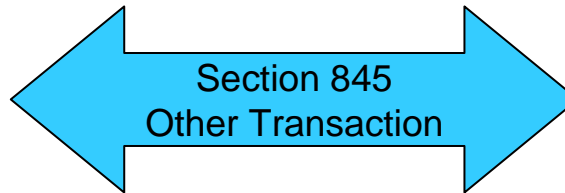
Ground Robotics Consortium

Purpose…

– Provide opportunity for non-government organizations to participate in DoD research planning, resulting in a plan based on industry expert knowledge of evolving technologies

Scope…

– Technology Development and Maturation

– Performance Improvement

– Autonomous Tactical Behavior Development

– Standard Maturation and Evolution

– Mission Equipment Package Integration

– Technology Transition Preparation

War Fighter Experimentation

- **Collaboration between Combatant Command and Combat Developer**

  – Institutional process for experimentation to underpin requirements analysis for "game changing" robotic technologies

  – "UGVs are significantly more complicated than UAVs, and will require much more experimentation." *- Army Science Board 2006 Summer Study*

Considerations for the Future

"We must focus our energies beyond the guns and steel of the military, beyond just our brave soldiers, sailors, Marines, and airmen. … I hear all the time from the senior leadership of our armed forces about how important these civilian capabilities are."

Secretary of Defense Robert Gates

"It is DoD policy that stability operations are a core U.S. military mission that the Department of Defense shall be prepared to conduct and support. They shall be given priority comparable to combat operations and be explicitly addressed and integrated across all DoD activities …

DoD Directive 3000.05, dated Nov 28, 2005

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Wearable Energetically Autonomous Robotics (WEAR)

• **Objective: Develop a class of robotic systems that are worn by humans, closely match the operator's motion in both space and time, and enable the wearer to carry heavy loads over rough terrain for extended periods of time.**

• **1995: DARPA exoskeleton effort begins**

• **2003: 1st powered lower extremity prototype**

• **2007: Responsibility transitioned to Natick**

• **Interest from the Requirement Developer (TRADOC)**

What's it going to do?

Sarcos's exoskeleton system

Combat Autonomous Mobility System (CAMS)

Problem:

• **Special Operations Forces personnel are operating for extended periods in wider ranging, increasingly austere, non-permissive areas against larger forces; all with resource constrained manpower.**

• **They lack robust organic capability to conduct timely tactical insertion, ground-based Intelligence Surveillance and Reconnaissance, and tactical re-supply, and the technology to effectively force-multiply available manpower.**

Solution:

Develop an integrated, autonomous, tactical ground-based system to leverage current Special Operations Forces manpower.

Test Implications

Ground Robotics Test and Evaluation: Are We Ready?

Million instructions/ second

Key Challenges
- *High speed mobility*
  - *Improved perception*
  - *Reliable data fusion*
- *Safe operations*
  - *Detect & classify stationary people & objects*
  - *Collision avoidance*
- *Design for tactical behavior flexibility*
  - *Understand environments*
  - *Decision processing*
  - *React appropriately to contact*
- *Collaboration*
  - *Conduct collaborative missions with mixed manned/unmanned force*
  - *Collaborative air-ground operations*

1B

10M

100K

1K

Air/Ground Collaboration

Crusher/DARPA

On-road convoy operations

Near autonomous team members

Armed Reconnaissance Vehicle—RSTA

Demo IIIa

True follower—follows in tracks of manned leader

1999   *2005*   *2008*   *2011*   *2015…*

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Effective Tests

Computer vision may not be as good as thought, according to MIT study

Cathryn M. Delude, McGovern Institute
January 24, 2008

- Apparent success may be misleading because the tests being used are inadvertently stacked in favor of computers

- Caltech101 database, intended to test computer vision algorithms against the variety of images seen in the real world

- Caltech101 'natural' images fail to adequately capture real-world variability

The human brain easily recognizes that these cars are all the same object, but the variations in the car's size, orientation and position are a challenge for computer-vision algorithms. Image / Nicolas Pinto

Robotics Acquisition Standards and Policy

JAUS and STANAG - Interoperability Standards Analysis (ISA)

- **There is a clear need for Department to establish policy for UMS standards**

- **Must find a way to harmonize "commercial" and "military" standards**

- **Frame of reference - systematically fuse JAUS and STANAG**

- **What is the path forward?**

  - **Using ISA as a starting point, develop a strategy and recommended policy for DoD**

  - **Looking to the creation of a Task Force of stakeholders to accomplish above (pre-decisional)**
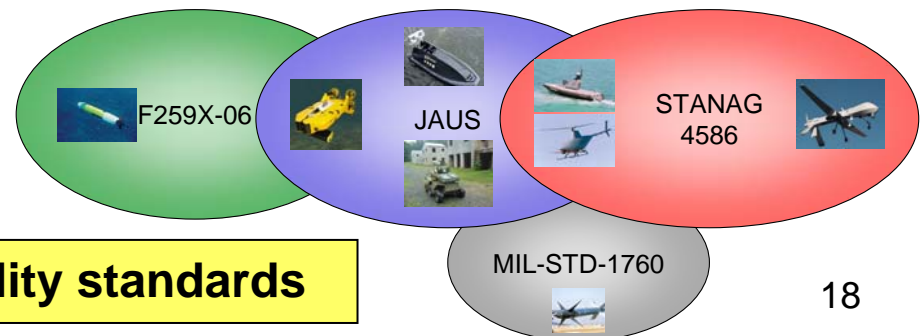
Bridge the gap between interoperability standards

Conclusion

- **A greater awareness of ground robotics is forming across the DoD:**
  - PACOM interested in for transport in complex terrain
  - SOCOM – CAMS JCTD
  - NORTHCOM looking to robotic tunnel exploration for border security
  - SOUTHCOM UXO - Range Clearance

- **Progress to Date**
  - Consortium
  - Integrated Roadmap

- **Technology is beginning to outpace concept development**
  - Experimentation is key
    - CAST War fighter Experiments 1 & 2
    - Exoskeleton Experiment

There is much to be done, and we are organized and committed to do it

Ground Robotics Studies and Strategic Planning

Richard Rumpf

Rumpf Associates International, Inc.

6 March 2008

Man is the best computer we can put aboard a spacecraft

... And the only one that can be mass produced with unskilled labor.

Wernher von Braun

Agenda

- OSD Goals for Unmanned Systems
- 2007-2008 JGRE Studies
    - Status
    - Recommendations
    - Actions
- Potential 2008-2009 Studies
- Ideas to Increase the Growth and Utility of Ground Robotics

Roadmap Goals

Goal 1. Improve the effectiveness of COCOM and coalition unmanned systems through improved integration and Joint Services collaboration.

Goal 2. Emphasize commonality to achieve greater interoperability among system controls, communications, data products, and data links on unmanned systems.

Goal 3. Foster the development of policies, standards, and procedures that enable safe and timely operations and the effective integration of manned and unmanned systems.

Goal 4. Implement standardized and protected positive control measures for unmanned systems and their associated armament.

Roadmap Goals

Goal 5. Support rapid demonstration and integration of validated combat capabilities in fielded/deployed systems through a more flexible prototyping, test and logistical support process.

Goal 6. Aggressively control cost by utilizing competition, refining and prioritizing requirements, and increasing interdependencies (networking) among DoD systems.

Unmanned Systems Roadmap Mission Graphic

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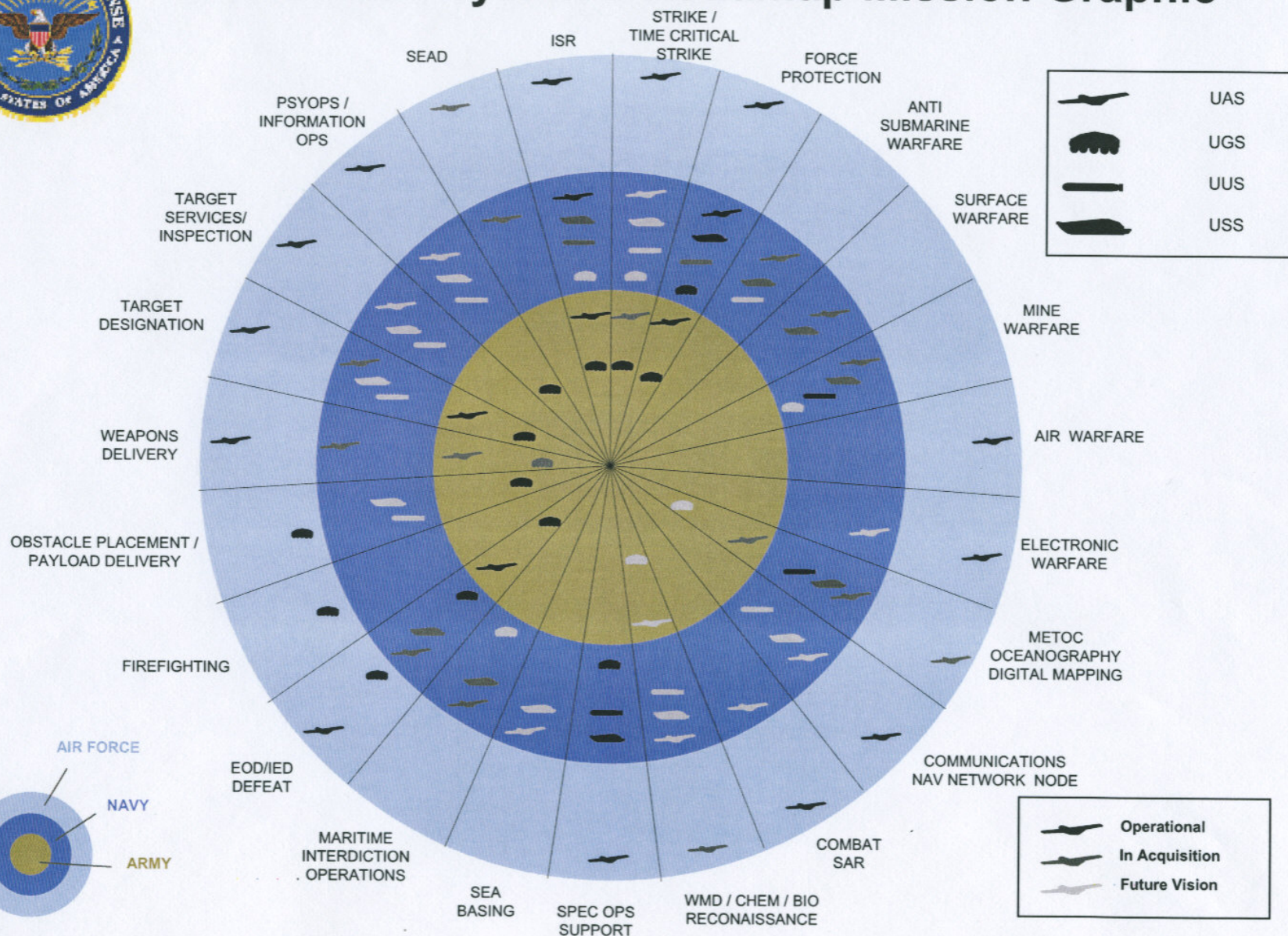
JGRE Studies

- JAUS/STANAG Interoperability Standards Analysis

- Unmanned Systems, International Technology Assessment

- UGV Robotic Industrial, Financial and Technology Industrial Base Assessment

- Spectrum Crowding Definition

- Joint Ground Robotics Common Controller Assessment

JAUS/STANAG Interoperability Standards Analysis

- Assessed ongoing UMS standardization activities and recommend a DoD UMS standardization strategy supporting improved interoperability, safety, and cost reduction

- Key Emerging Findings / Recommendations
  - STANAG 4586 is "NATO Unclassified" which reduces the number of viable coordination solutions
    - Only NATO countries can obtain the standard
  - JAUS and STANAG 4586 agree that a Service Oriented Architecture (SOA) is required to support future interoperability needs

International Technology Assessment

- Provided an assessment of International R&D efforts in ground robotics

- Initial research: foreign systems, key subsystems, and enabling technologies well underway

- State-of-the-art in deployed systems appears to be substantially limited to remotely-controlled or tele-operated systems with limited autonomy

- Significant research being done within the US and abroad on increasing autonomous capabilities of ground robotics

- Distinct geographical differences in competencies and development foci as a function of research traditions, funding sources, and R&D performers

Key Elements of Ground Robotic Technology
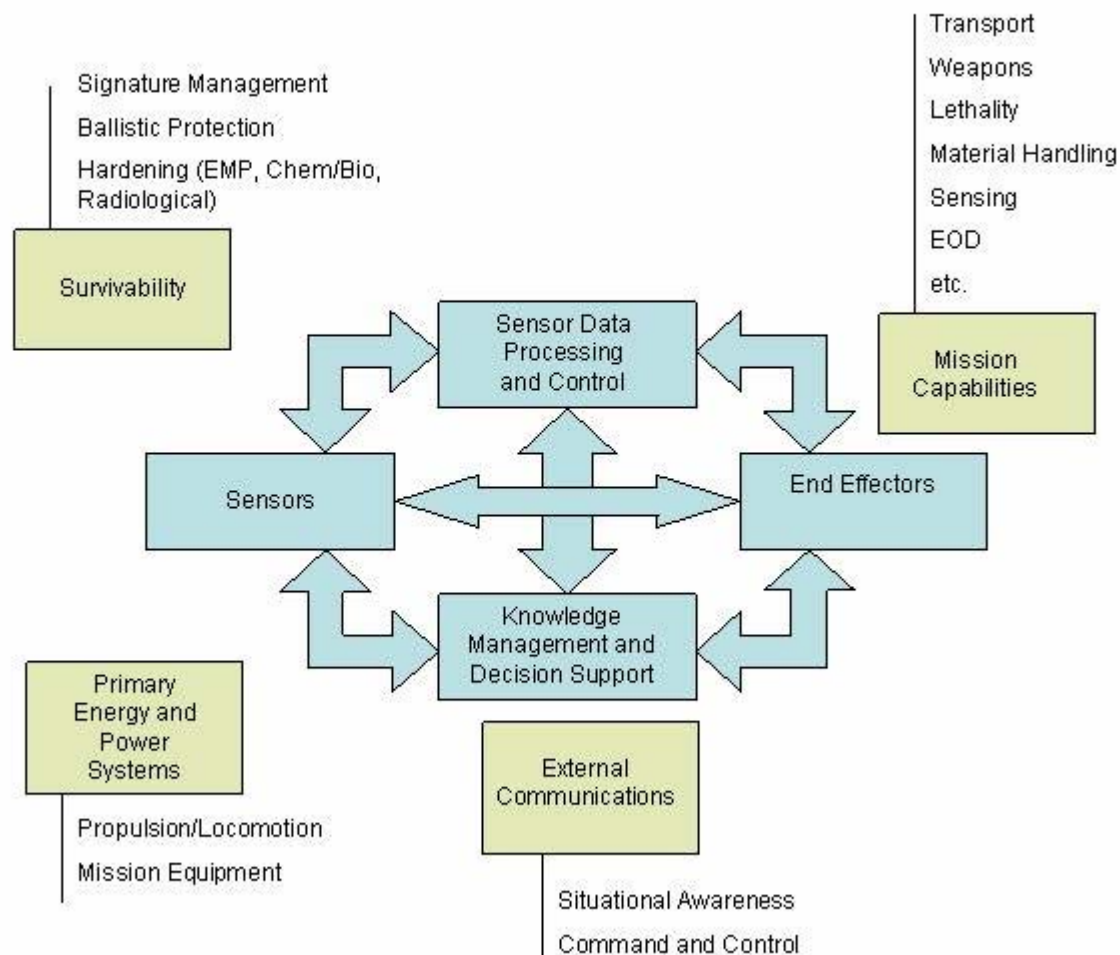
Overview of Activity in Ground Robotics
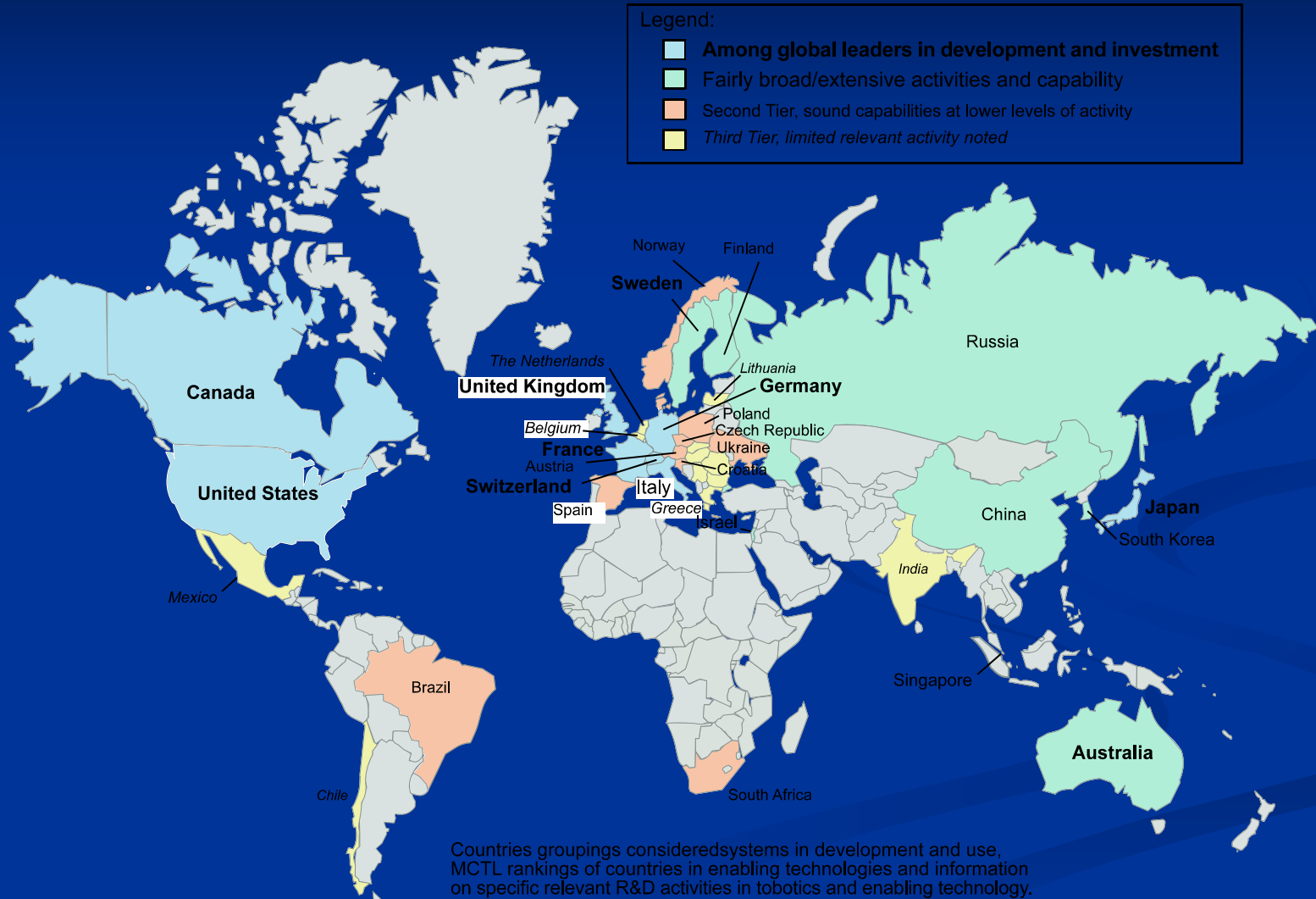
UGV Robotic Industrial Base Assessment

- Determined short & long term ability of the U.S. industrial base to support the production of UGV systems to meet current and emerging DoD requirements
- Lack of competition for UGVs
    - Results in higher prices
- Limited environmental testing or high-rate production capability
- Majority of suppliers using COTS subsystems
- Barrier for smaller companies that traditionally have not performed DoD work in the past
- Most companies agree that JAUS will take UGV/Robotics to the next step

Spectrum Crowding Definition

- Provide a comprehensive review of the spectrum requirements and factors impacting the communications links of existing unmanned ground systems and those under development

- Joint Spectrum Center (JSC) of the Defense Spectrum Organization assisting to define potential UGS/V communications-electronics system problems with regard to spectrum availability, utilization and interference

  - Comprehensive review will provide spectrum requirements and factors impacting the communications links of existing and developing UGS/V with a view toward increasing the reliability and operational effectiveness of unmanned systems

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Common Controller Assessment

- Study was to recommend characteristics and definition of a Universal Controller/Architecture (URC/A) considering current systems for robotic control, operational implications, future growth and needs, and technological paths forward

- Study assumed that a common controller is necessary

- All identified past and ongoing robot controller programs were reviewed and evaluated

- Characteristics and definition of a Universal Robot Controller/Architecture were drafted with reasoning and support

Robotic Evolution
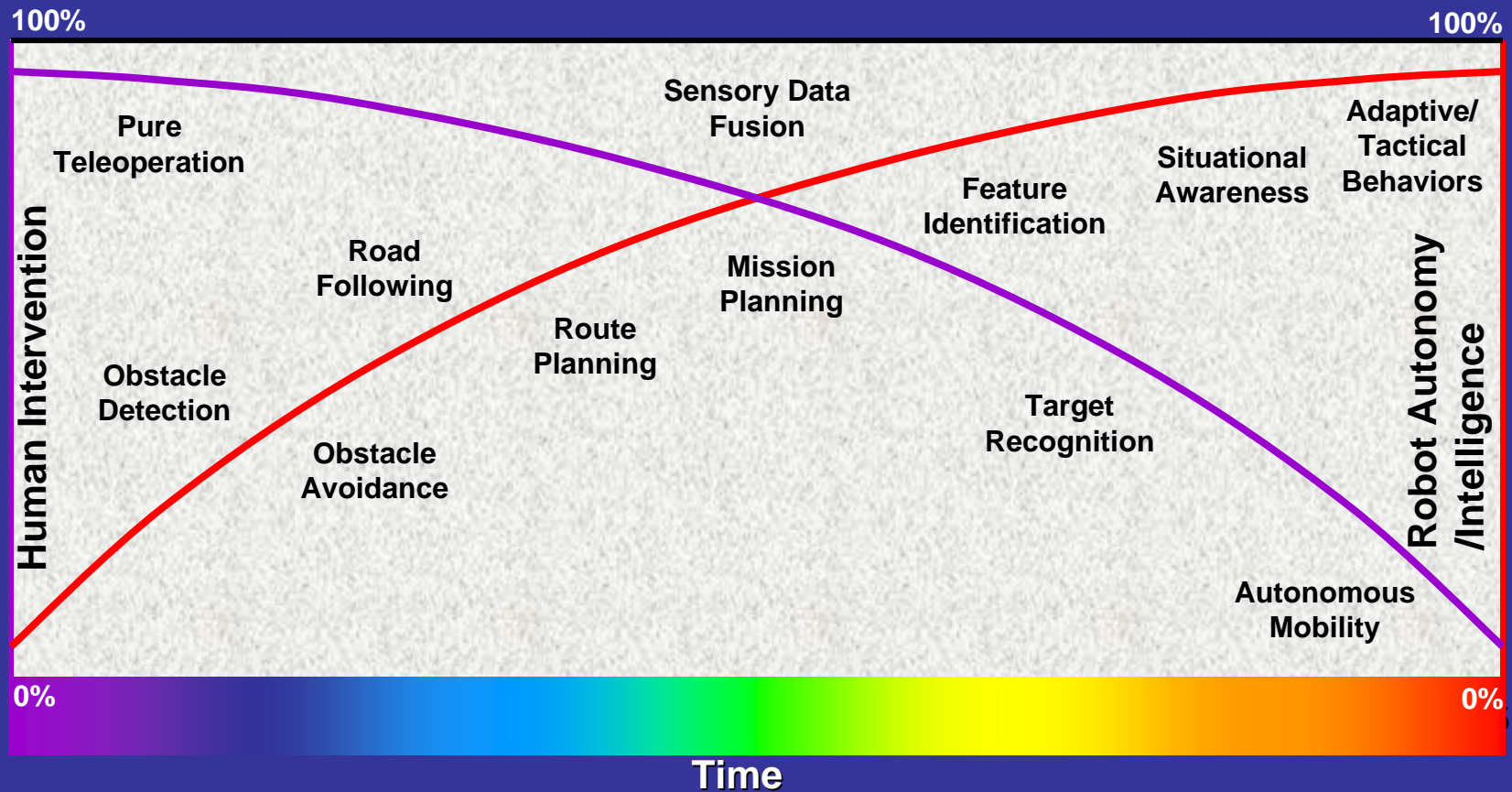
Potential 2008-2009 Studies

- UxV System Reliability

- UxV Interoperability

- UxV Sensors / Payloads

- UxV Systems / Subsystems

UxV System Reliability

- Study the fielded support elements, e.g. spares, maintenance, training, to determine the impact and trade-off of designed-in reliability on the total cost of ownership and user reliance on robotic systems
- Evaluate current and ongoing UGV programs and gather lessons learned from UGVs and UAS programs used in OEF and OIF
    - Examine a non master-slave concept where control algorithms on the whole will promote all swarm or other like-functioning robots to accomplish their task
    - Understand how communication bandwidth effects rate of how fast systems will accomplish their tasks

UxV Interoperability

- Multi-Robot Control
- Near-Autonomous UxV Systems
- Enhanced Human/Robot Interaction and Teaming
- 3-D Map Visualization
- Intelligent Mobility
- Obstacle Avoidance
- Standards (e.g. JAUS, STANG 4586, et.al.)
- Data Links
- Cognitive Science Application to Operator Training and Performance

UxV Sensors / Payloads

- **COTS Sensors Catalog**
  - Performance, Reliability, Cost, Modularity, Technology Insertion/Refresh Ability, Open System Architecture Compatibility, Maturity, etc.
- **Lethal and Non-Lethal Payloads and Controls**
- **Restrictions**
  - ITAR
- **Current and Possible Future Rules of Engagement Capabilities and Gaps**

UxV System / Subsystem Applications

- Examine UxV Systems and Subsystems in development or fielded by NASA, DOE NSA, CIA, NIST for applicability to DoD missions

- Determine best process to collaborate on development of common use systems / subsystems for purposes of speed to the user, interoperability, reduced cost, common training (if possible)

What Inhibits the Growth and Utilization of Ground Robotics?

- Acquisition Policy
  - Joint Capabilities Integration Development System (JCIDS) defines the process to become a Program of Record (POR)
    - For Items like ground robotics, the JCIDS/5000 Process is long, restricts easy introduction/fielding of new concepts by its rigid budget and planning process

What Inhibits the Growth and Utilization of Ground Robotics?

- Non-Acquisition Approaches
  - Examples: JCTD, QRF, INP, TTI, FCT, etc.
  - These approaches are primarily for demonstration of technology
  - Do not include Life Cycle planning or logistics support
  - Limited funding
  - May require Cost Sharing
  - May require Technology Readiness Level (TRL) of 6-7 at entry and must achieve TRL of 8-9 within 2 years
  - Some are limited to less than $2M without a commitment of production from a POR, etc.
  - These programs can help <u>but</u> are not the answer

What Inhibits the Growth and Utilization of Ground Robotics?

- Short-Term Thinking
  - Procurements for OIF/OEF are short durations, heavily COTS-laden, and many lack Life Cycle Planning, Logistics Support, and Systems Engineering
  - These elements are necessary to gain the confidence of the Warfighter in the field or the Sponsor in the Pentagon

Small Business Issues Breakout Panel

➤ Focus was on issues related to how small, especially non-traditional, businesses can become involved in the DoD acquisition process.

Presentors

- ✓ Robotics Technology Consortium, **Bill Thomasmeyer**, President NCDR
- ✓ SBIR Program
  - ✓ **Todd Jochem**, Group Director, Foster-Miller, Inc.
  - ✓ **Jill Dickman**, SBIR Program Manager, Small Business Development Center, University of Texas
- ✓ Large/Small Company Partnerships, **Kirk Kirkpatrick,** Manager of Business Development for Combat Maneuver Systems, Lockheed Martin
- ✓ Mentor-Protégé Program - **Sathedia Bush,** Chief, USAF Mentor Protégé Program

Key Points

➢ Proposed Robotics Consortium represents a promising means to cast a wider net and engage small, non-traditional companies to apply their robotics technology for defense related solutions

➢ SBIR program represents a terrific opportunity for small businesses to develop robotics related technologies

➢ Large companies are actively seeking partnership, licensing, and acquisition opportunities with small companies

➢ Mentor-Protégé program is a great complement to SBIR program

SBIR Program

➢ DoD SBIR Funding total approximately $1.1 Billion

➢ Majority of Funding goes to companies with less than 25 employees

➢ Phase II Plus and Fast Track program represents terrific leveraging and prioritization opportunities

➢ Need to look at opportunities beyond DoD

➢ Phase II SBIR Contracting is a challenge

➢ Phase III gap and time it takes to transition even the most promising technology to procurement is a problem for small companies

➢ Current SBIR program expires at end of FY08 and renewal is a political challenge

➢ Proposal to allocate 1% of SBIR funds to expand Mentor-Protégé program is a good idea

Recommendations

• Devise an end-to-end strategy to proactively coordinate and leverage JGRE funding with SBIR opportunities

- •JGRE funding could be used to leverage Fast Track and Phase II Plus funding opportunities
- • JGRE Funding could be used to help fill Phase III gaps

• Advocate for SBIR renewal and proposal to extend Mentor-Protégé program to SBIR participants

• Devise means to monitor SBIR opportunities and communicate these to small & non-traditional companies

• Devise means to help small & non-traditional companies to establish working relationships with SBIR program managers and technical points of contact

Recommendations

- Devise means to educate small, non-traditional companies on SBIR opportunities, process, implications, etc. and provide support services

- Devise means to research SBIR data bases to identify technologies resulting from past Phase II projects with UGV applicability

- Devise means to help small, non-traditional companies form partnerships with large companies on the front-end of SBIR opportunities

- Investigate possible use of OTA to put Phase II SBIR projects under contract

(Name) Breakout Panel Next Step

➢ Recommendations (if other than on previous slides)

Technology Long Poles Introduction

1. Workshop overview and procedures used:
   - 50+ attendees and five panelists participated
   - Formal presentations initiated the discussions
   - Audience introduced themselves noting interests

2. Process to ID Technology Longpoles was to:
   - Brainstorm to capture everyone's ideas (no filter)
   - Categorize technologies into a few major topics
   - Prioritize entire list (25) into top five and top 9

3. Consensus voting was used to rank all items
   - Everyone voted for their top five to rank top 9
   - Everyone voted for their top two to rank top five
   - Winner was the Situational Awareness category

Technology Long Poles (Continued)

1. Additional Workshop Procedures Used:
   - A running summary of notes was written
   - Technology candidates were all debated
   - All wording was reviewed and corrected
2. Policy issues removed as non-Long Pole
3. Thoughtful insights shared on paradigms
   - Technologies not enough in/of themselves
   - Changes in US concepts are also required
   - Unmanned from start + unmanned logistics
4. 25 Long Poles in five categories prioritized:

Technology Long Poles (Top 5) (Top 9)

1. C4
   - Human-machine interface focused on planned events (EBP)
   - **Control of the army of robots in a multi-robot environment**
   - Ability to do close-in operation robustly and remotely
   - **Secure and reliable communications is a vulnerability**
   - Mixed (Sliding) autonomy (build trust)
   - Decentralized parsing of tasks
   - Effective control of an autonomous weapon/failsafe (FMEC)
2. SSA
   - Perception methodologies for sensor strategies amongst teams of robots
   - Robot to explore to determine intent (engage it actively)
   - **Presenting current state to operator and to robot**
   - Human visibility (operator's intent)
   - Threat inference prediction
   - Robot Self-awareness
3. ACT
   - Planning for heterogeneous systems (planning for dissimilar systems)
   - Taxonomy of achievements
   - Safety for industrial interactions aimed at robot-human interactions and for manned unmanned systems
4. SYSTEMS ENGINEERING
   - **Power Generation &/or storage**
   - Families of cascading unmanned systems as a solution
   - Modular design is not routine
   - Minimum set of components to deliver functional capability
   - Standards across the industry driven by scale
   - Design for robotics assembly could be an enabler
   - Creating simplicity (improved decision accuracy by inferences)
5. LOGISTICS
   - Power management (air refuel-able as an example)
   - **Reliability and availability (designed in) especially for weaponized process**

Technology Long Poles (Top 5) (Top 9)

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    - Creating simplicity (improved decision accuracy by inferences)

Technology Long Poles Results

1. Summary of Long Pole workshop results:
   - Excellent participation by all attendees
   - Thought-provoking panelists briefings
   - We did not lack for opinions nor ideas
   - 25 Technology Long Poles were listed
   - All fit in Five representative categories
   - Top 9 Long Poles prioritized by voting
   - Top 5 Long Poles selected by consensus
   - Thank you to panelists and all attendees
   - Special thanks to Phillip Koon for note taking
2. Top 5 should keep us busy for 10 years

Robotics in Homeland Defense

Purpose: To discuss the capability gaps in the mission sets of homeland defenders that would lend themselves to the introduction/enhancement of ground robotics applications

Panelists:

Jim Russell – Air Combat Command (Chair)

Larry Burns – Las Vegas Metropolitan Police Department

John Gnagey – National Tactical Officers Association

Kim Keisling – Joint Task Force North

Darron Lee – Drug Enforcement Administration

Tom Lynch – National Tactical Officers Association

Shan Smith – Immigration and Customs Enforcement

Greg Torres – U.S. Customs and Border Protection

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Robotics in Homeland Defense

- **Identified 3 major user communities**

  - **EOD/bomb squad**

  - **Tactical Operations (CT/LE)**

  - **Tunnel Task Force (DEA/ICE/USBP)**

Robotics in Homeland Defense

- **All users have different missions and different robotic requirements**
  - **EOD/Bomb squads**
    - **Need robotic capabilities for dealing with suicide bombers and VBIEDs**
    - **Require the ability to transport a heavy load down range**
  - **Tunnel Task Force**
    - **Need capability to operate below ground**
    - **Must operate in various geological conditions**
  - **Tactical Operations**
    - **Must be untethered, agile, stable, and have ability to deploy various tactical payloads**
    - **Need tactical operations robot vice EOD robot**

Robotics in Homeland Defense

Requirement Documentation Challenges:

- **No formal documentation has been developed**
- **US NORTHCOM is COCOM**
- **Counter Tunnel is number 4 for US NORTHCOM**
- **All aspects has not been articulated**
- **JTFN has drafted a prelim needs doc**
- **DOD and TSWG are tackling the programming**
- **Urgent Compelling document from JTF 134 for Counter Tunnel Operations could be basic document**
- **Threat documentation is being produced by DIA**

Robotics in Homeland Defense (Technology Thrust Areas)

Platform

- **Stability and Size – multiple sizes required/must be mission adaptable**

- **Power – batteries and or external power source**

- **Mobility – able to transverse water, mud, clay, steep slopes, dry dusty areas, snow, etc**

- **Advanced Materials – maintenance costs must be low**

- **Terrain and Environments – arid, wet, snow etc**

- **Survivability – capable of withstanding 7.62mm direct fire**

Robotics in Homeland Defense (Technology Thrust Areas)

Communication

- **Frequency Allocation – needs to be determined**

- **Security – needs to be able to operate in a cluttered EMI environment**

- **Range and Bandwidth – needs to be determined**

- **Satellite Systems – needs to be able to data up and down link**

- **Wireless Communications – needs to be able to accept other wireless systems as demanded by mission profile**

- **Tethered vs Radio Frequency Systems – should be able to do both**

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Robotics in Homeland Defense (Technology Thrust Areas)

Control

- **Human Factors** – systems operated in extreme stress situations, needs to be intuitive

- **Feedback Systems** – platform needs to be semi-aware

- **Multiple Vehicles** – capable of co-operating with other similar and dis-similar systems

- **Operator Control Stations** – prefer stand alone due to keyboard complexity and the KISS principle

- **Voice Command Recognition** – ??

- **Level of Onboard Intelligence**

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Robotics in Homeland Defense (Technology Thrust Areas)

Navigation

- **Tele-operation – to be determined**

- **Semi-Autonomous/Autonomous – some tasks should be semi-autonomous**

- **Path Planning – mission dependent**

- **Object Recognition – yes**

- **Obstacle Detection/Avoidance – yes**

- **Positioning Systems/mapping – yes**

Robotics in Homeland Defense (Technology Thrust Areas)

Payloads

- **Chem/Bio/Rad Sensors**

- **Anti-terrorism Tools**

- **Defeat Systems**

- **Sensors**

- **Intelligence Gathering Systems**

- **Construction Tools**

Robotics in Homeland Defense (Technology Thrust Areas)

Manipulation

- **Degrees of Freedom**

- **Force Feedback**

- **Operator Control**

- **Automation/Intelligence**

- **Precision/Accuracy**

- **Dexterity/Lift Capacity**

Robotics in Homeland Defense (Conclusion / Recommendation)

- **Tactical Ops and Tunnel Task Force robotic requirements not clearly identified**
  - **Need methodology to define needs...may seek to leverage EOD/Bomb squad process for requirements identification and advocacy**

- **Recommend working with JTFN, TSWG, and JGRE for support to help in requirements development**

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Robotics in Homeland Defense

My sincere thanks to the members of the Panel....

Questions???

Robotics in Homeland Defense

- **Purpose:** To discuss the capability gaps in the mission sets of homeland defenders that would lend themselves to the introduction/enhancement of ground robotics applications.

- **Panelists:**

-        **Jim Russell – Air Combat Command (moderator)**
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-        **Kim Keisling – Joint Task Force North**
-        **Darron Lee – Drug Enforcement Administration**
-        **Tom Lynch – National Tactical Officers Association**
-        **Shan Smith – Immigration and Customs Enforcement**
-        **Greg Torres – U.S. Customs and Border Protection**

Robotics in Homeland Defense

Law Enforcement

- **Aside from bomb squad / EOD, law enforcement is not quite sure how / what a robot can do for them**
  - **Do not know what questions to ask**
  - **Education process is essential**

- **Bomb squads**
  - **Need robotic capabilities for dealing with suicide bombers and VBIEDs**
  - **Getting down range quickly for a VBIED is a priority**
  - **Also require the ability to transport a heavy load down range**

Robotics in Homeland Defense

Tactical Operations (CT/Law Enforcement)

- SWAT guiding documents being developed on a national level (currently none in existence)
  - Mission analysis with related activities and tasks
  - Standardization
  - Equipment lists
- Still adapting EOD platforms to do tactical missions

Robotics in Homeland Defense

- Tactical robotic systems devices must be un-tethered
- Maneuverability is a huge challenge
  - Need to move in hallways / inside doorways, up stairs, etc.
  - Look / display and move about in extremely cluttered spaces
- Must be stable
  - For example, must be able to break and rake a window
- Intelligence gathering prior to an entry is most valuable
  - Introduce robotics into the environment and feedback information remotely
  - Need to know what's in there before entry, for example:
    - People, substances, devices, etc.
    - Pinpoint the location of the suspect

Robotics in Homeland Defense

- **Interface / Operator Control Unit**
  - **Prefer dedicated OCU with a large monitor**
  - **New generation of operator has more dexterity (video game generation)**
  - **Sensors for orientation**
    - **3D awareness of situation**
    - **E.g., keep equidistant from walls when going up stairs**
  - **Require telemetry to command center and others**
    - **Not just to the commander on scene, but back to the operation center**
    - **Monitor for operators up front would be ideal (can see for themselves)**

Robotics in Homeland Defense

- **More:**
  - **Next gen robot should have Artificial Intelligence (AI)**
  - **RF always better, tethered robots can easily be disconnected by criminal**
  - **Need a small UAV to launch from the robot to see on upper windows**
  - **Robot is better than face-to-face with the criminal**
    - **Cannot hurt the robot with gunfire**
    - **Does not see it as human**
    - **LVMPD has found that they can resolve a hostage crisis 75% faster with a robot**
  - **Due to legal action it will become increasingly difficult to classify a SWAT team if they do not have certain equipment sets**
  - **Larger robots are good for VBIED etc**

Robotics in Homeland Defense

- **DEA/ICE/USBP - Tunnel Task Force**
- Background Information
  - 75 tunnels (74 on SW border, 1 on Northern border) discovered since 1991
    - **62 of these discovered since 2001**
  - Range of depths: 10-90' at entrance
  - Irregular, square drops within tunnels
  - Range of lengths, sophistication
  - Rough concrete flooring (at best)
  - One entrance / one exit
    - **Can have offshoots**

Robotics in Homeland Defense

- **Missions (not formally documented / articulated at this point)**

  - **Surveillance**
  - **Intelligence Gathering**
  - **Rescue**
  - **Search**
  - **Hazmat Incidents**
  - **Radiation monitoring**
  - **Post event assessment**
  - **Fire Fighting (forest and urban)**
  - **Detect the tunnel**
  - **Survey for environmental safety**
  - **Map the tunnel**
  - **Interdict (possibly)**
  - **Exploit the tunnel (if safe environment)**
  - **Collect Evidence**
  - **Remediate (e.g., fill the tunnel)**

Robotics in Homeland Defense

- **Experimented with robotics in the past – acquired from SPAWAR, but have since returned**
  - **Taking robots meant to be run above ground and attempting to make fit the task force's needs (e.g., working underground)**
  - **Presence of water, mud, sludge, dark, lack of communication, etc. made this difficult**
  - **Eventually required too much effort to utilize effectively**
  - **Had three systems**
    - **Small robot – 14" long and approx 30 lbs**
    - **Scout – bigger, fiber optic system**
      - **Fiber optic was too fragile**
      - **Backing up was difficult**
    - **Vanguard system**
      - **Never deployed – too big**

Robotics in Homeland Defense Operating Environment

- **Largely private land along the border**
  - **Only a 60'-wide easement along the border is accessible for federal law enforcement**
  - **No tunnel boring machines (hand dug and pneumatic hand tools used)**
  - **Tunneling market will likely grow**
    - **As the border fence expands**
    - **Currently, geographically centralized around industrial areas**
  - **Zero rate of interdiction (as seen by criminals) – unlike more risky land/port of entry crossings due to dogs and unscheduled inspections**
  - **Different geology / soil creates problems for robots, for example:**
    - **Sand**
    - **Water**
    - **Sludge**
    - **Clay**
  - **No light in the tunnels**
    - **Night vision does not work**

Robotics in Homeland Defense

- **Detecting tunnels not currently an option**
  - **Different problem set that is being worked elsewhere**
- **Post-discovery capabilities are what is required – all currently performed manually**
  - **Once discovered, every tunnel is swept for CBRN by a National Guard Civil Support Team**
  - **Dangerous due to lack of shafting and shoring and possibility of earthquake**
  - **Must also clear tunnel tactically for safety**
  - **Tunnel must be completely surveyed / mapped within 24 hours**
  - **Evidence is recovered for law enforcement purposes**
  - **Tunnel must be filled within 30 days (by CBP), as per Congressional mandate**

Robotics in Homeland Defense

- **Requirements list never formally documented / articulated (JTFN has developed a rough draft)**
  - **Would ultimately desire robotically / autonomously ability to:**
    - **Determine where to dig**
    - **Surreptitiously find and investigate tunnel**
    - **Send in robot to traverse tunnel to:**
      - **Test environment to determine safety**
      - **Map environment to survey the length / extent of the tunnel**
    - **Need more maneuverability**
      - **Weight of tether an issue – if running a co-axel type cable**
      - **Some tunnels are too long**

Robotics in Homeland Defense

- **Other tunnel-related issues:**
  - **Pipe inspection robots (e.g., sewer pipe inspectors)**
    - **Have been tried in the past**
    - **Developed for smooth surfaces/pipes**
    - **Difficult terrain and obstacle strewn about within the tunnels (e.g., digging tools) makes using these devices difficult**
    - **Smooth pipes have regular manhole for insertion/extraction of robot**
  - **Program office in being stood up in DoD for tunnels**
    - **Technical Support Working Group (TSWG) is releasing Broad Agency Announcement (BAA)**
    - **TSWG.gov**

Robotics in Homeland Defense

- **Other tunnel-related issues (cont'd):**
  - **Tunnel testing environments**
    - **Discovered tunnels must be filled immediately, so not an option for testing**
    - **OSD AT&L is planning a test facility**
    - **MOU is being worked between DoD (TSWG) and Israel to develop a joint tunnel test bed**
    - **One tunnel found had 3 drops, longest drop 20ft with improvised ladder and 30% gradient concrete steps**
  - **Use of inert gas for mapping?**
    - **No legal agreement to use**

Technical Needs
TECHNOLOGY THRUST AREAS
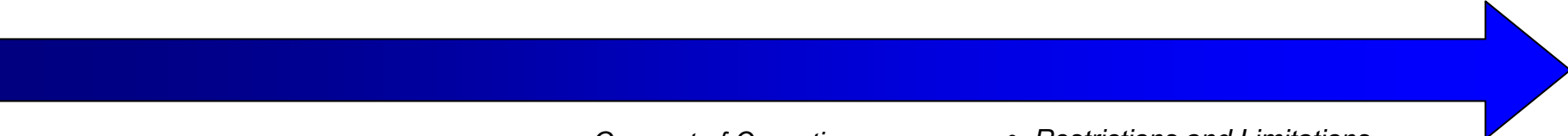
Operational Analysis
- *Concept of Operations*
- *What are the Threats*
- *Warfighter Needs*
- *Restrictions and Limitations*
- *Shortfalls of Existing Systems*
- *Planning, Programming, and Budgeting*

Platform(s)
- *Stability and Size*
- *Power*
- *Mobility*
- *Advanced Materials*
- *Terrain and Environments*
- *Survivability*

Communication
- *Frequency Allocation*
- *Security*
- *Range and Bandwidth*
- *Satellite Systems*
- *Wireless Communications*
- *Tethered vs Radio Frequency Systems*

Control
- *Human Factors*
- *Feedback Systems*
- *Multiple Vehicles*
- *Operator Control Stations*
- *Voice Command Recognition*
- *Level of Onboard Intelligence*

Navigation
- *Teleoperation*
- *Semi-Autonomous/Autonomous*
- *Path Planning*
- *Object Recognition*
- *Obstacle Detection/Avoidance*
- *Positioning Systems*

Payloads
- *Chem/Bio/Rad Sensors*
- *Anti-terrorism Tools*
- *Defeat Systems*
- *Sensors*
- *Intelligence Gathering Systems*
- *Construction Tools*

Manipulation
- *Degrees of Freedom*
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Robotics in Homeland Defense

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- *Operator Control Stations – prefer stand alone due to keyboard complexity and the KISS principle*

- *Voice Command Recognition – ??*

- *Level of Onboard Intelligence*

Robotics in Homeland Defense

Navigation

- *Tele-operation – to be determined*

- *Semi-Autonomous/Autonomous – some tasks should be semi-autonomous*

- *Path Planning – mission dependent*

- *Object Recognition – yes*

- *Obstacle Detection/Avoidance – yes*

- *Positioning Systems/mapping – yes*

Robotics in Homeland Defense

Payloads

- *Chem/Bio/Rad Sensors*

- *Anti-terrorism Tools*

- *Defeat Systems*

- *Sensors*

- *Intelligence Gathering Systems*

- *Construction Tools*

Robotics in Homeland Defense

Manipulation

- *Degrees of Freedom*

- *Force Feedback*

- *Operator Control*

- *Automation/Intelligence*

- *Precision/Accuracy*

- *Dexterity/Lift Capacity*

Robotics in Homeland Defense

- Definitive need for robotic systems
- Current systems do not meet needs and specific operating environments
- Disparate users need systems with like capabilities
- Some currently fielded system could be modified for effective use but would not be ideal to mission
- More detailed requirements definition must be articulated.
- Continue the socialization process at all levels

Robotics in Homeland Defense

- Questions/Comments???

- Thank you very much

Ground Robotics Capabilities Conference and Exhibition

Break Out Session: Combat Support / Combat Service Support Issues Working Group

6 March 2008

Chair: LTC Chris Day, Sustainment Battle Lab- CASCOM

Topic Highlights

➢ **Topic A (Autonomous Convoy)**

Issues:
- ✓ Affordability
- ✓ Systems Integration to legacy equipment & process
- ✓ Operations in all environments (complex and dynamic)
- ✓ Trust in automation / robotics (reliability)
- ✓ Secure and reliable communication in all environments
- ✓ Legal and regulatory constraints / liability

Potential Resolution of Issues:
- ✓ Use of COTS
- ✓ Lower cost sensors
- ✓ System with open architecture – ability to Plug & Play
- ✓ Automation ready- "fly by wire"
- ✓ Collaborations (industry and user)
- ✓ Engineering reliability in system
- ✓ Experience / Exposure to robots (Testing / Training in and to required environment)
- ✓ Communication independent solution

Topic Highlights

➢ **Topic B (User Assist Technology)**

Issues:
- ✓ Power
- ✓ Affordability
- ✓ Systems Integration to CSS processes & their execution (info systems, size, vehicles)
- ✓ Operations in all environments (complex and dynamic)
- ✓ Trust in automation / robotics (reliability)
- ✓ Soldier safety concerns / liability

Potential Resolution of Issues:
- ✓ Collaborations (industry and user)
- ✓ Optimizing power management and energy efficiency
- ✓ Lower cost sensors
- ✓ System with open architecture – ability to Plug & Play
- ✓ Engineering reliability in system
- ✓ Experience / Exposure to robots (Testing / Training in and to required environment)

QUESTIONS?

Operational Issues / Challenges

Breakout Panel

Questions

- **What capabilities can unmanned ground systems bring to operational mission areas?**

- **What technologies must be developed to enable the development of these capabilities?**

- **What tactical and doctrinal issues need to be addressed to allow for a smooth transition of these capabilities to the Warfighters?**

- **What actions need to be taken as part of the path forward to overcome the technological, tactical and doctrinal issues identified?**

What mission sets do we want Unmanned Ground Systems for?

Force Protection
> **EOD / UXO**
> **Route clearance / mobility / demining / area clearance**
> **Firefighting**
> **Decontamination**

Logistics
> **Transportation / haul**
> **Battlefield medical applications**
> **Refuel / resupply**
> **Humanitarian Assistance / Aid**

Reconnaissance
> **Perimeter / Site Security & Early Warning**
> **Short range – "around the corner"**
> **Long range – "outside weapons range"**
> **CBRNE sensing / ID**

Direct Contact
> **Lethal effects**
> **Less than lethal effects**

Q1 – Capabilities / Requirements

- Sensory Feedback to the operator – SIGHT, touch, sound

- Virtual environment – with seamless man-machine interface

- Environmental Hazards Detection and Identification – Hazardous military and industrial chemicals, explosives, radioactive materials

- Suite of systems – Recon, Action (movement / manipulation) – one size does not fit all – vehicle-delivered vs map packable system

- Add 3D Dimension – GMAV – but without requiring airspace coordination

- Plug and Play architecture – adding / removing capabilities – needs to enable the user to add sensors / tools to the system easily – from different manufacturers

- Strongly prefer Wireless devices

- Must be night capable

- Must be compatible with Counter-IED Remote Control Electronic Warfare (or CREW)

- Must improve ranges in urban environments

Q1 – Capabilities / Requirements

• Must be able to fix forward – transportation on the non-linear battlefield is at a premium – Soldiers trained to repair with repair parts inventories on-hand

• Must reduce cost

• Material Reliability

• Appropriately weight classed – small, medium and large. Weight reduction / portable within its weight class

• Commonality of controllers / user interfaces

• Long duration; power supply sufficient for sustained operations

• All-weather capable

• Highly mobile – undeterred by mud, shallow water, rubble, etc

• Self geo-referencing; mapping

• Creating 360 degree visual and aural environment

• Autonomous movement and autonomous task operations

Q2 – Technologies

- **Intelligent actuators**

- **Advanced materials – composites, plastics, alloys?**

- **Energy storage – increasing energy and power density**

- **Virtual displays that recreate human senses**

- **Precise navigation in GPS-denied environment**

- **Reliable, long-range, non-LOS communications; programmable frequencies**

- **Advanced sensors and sensor integration**

N/A

Q4 – Future Actions…

- **Combat Developers; increased feedback / input from end users.**

- **Integrated, full life-cycle support.**

- **Establish specific cost targets / ceilings.**

- **Supply chain analysis to determine necessary infrastructure required to support robotics industry.**

Interoperability Breakout Panel

➢ Examine current interoperability standards for unmanned systems and develop a path forward for achieving interoperability across all unmanned systems.

Panelists

➢ Robert Wade
  ➢ Chair of SAE AS-4A (JAUS)
➢ Keith Wheeler
  ➢ Custodian of STANAG 4586
➢ LTC (ret.) Kerry Pavek & MAJ Clarence White
  ➢ FCS User Requirements

Session Framework

➢ Interoperability means different things to different people
- Interfaces
- Architectures
- Software and hardware

➢ Group concentrated on the command and control (C2) standards impact on interoperability

Session Summary

➢ Identified key issues surrounding interoperability for unmanned systems

➢ Generated a list of recommended actions based on those issues identified during the session

Key Issues

- **Definition of "interoperability"**
  - **Joint Pubs update to include this new arena?**
    - Current interoperability definitions concentrate on data exchange, not control of UMS
  - **Related to other UMS vernacular issues**
    - Difficult without a common way to dialog (language/definitions)
    - NIST ALFUS/AS-4D/ASTM F41/NATO/EDA-EDU/Joint Pubs/Service Pubs are just some of the places with definitions

Key Issues

- **Better definition needed in the expression of "how interoperable we are/need to be"**
    - **e.g. Levels of Interoperability (STANAG 4586) and Levels of Control (TCS and FCS ORDs)**
    - **How should the services decide what will be interoperable?**

- **Need for Physical standards?**
    - **Or is that too deep/too complex to address from OSD level**
    - **"plug and play" issue**

Key Issues

- **Assured Compliance**
  - Is there a solid method of measuring compliance?
  - Do we need the "Underwriters Lab" of UMS control?
    - JFCOM, JITC for Joint interoperability certifications?

- **Multiplicity of Standards**
  - Multiple standards may or may not be an issue
  - Answer is bedded in the "vision"
    - How many "languages" will be allowed or will we neck down to ONE.
  - Costs are a key element of that decision
    - Can we afford to continue with multiple standards?
  - Need to ID what is the commonality/differences to support the decision

Key Issues

- **Security**
  - **Authorizations**
    - **Permissions**
    - **Training**
  - **Authentication**
    - **UMS only responds to authorized user**
  - **Impact of Open Architectures direction?**
    - **Classification guide implications?**
  - **COMSEC**
    - **Where is appropriate place for that security layer**
  - **Anti-Tamper and Layered Self-defense of UMS**

Key Issues

- **Safety**
  - **Improvement in "Hand off" of control**
    - **TTP development support**
  - **Other Safety considerations**
    - **Control interface functionalities match the UMS functionalities**
    - **Software safety (safety critical code)**
  - **E-Stop guidelines**
    - **Interference**

- **Lessons Learned library of UMS implementation?**
  - **Documenting and sharing experiences**

Key Issues

- **Policy Guidance Needed**
    - **Clear articulation of the intent and scope**
        - **What is OSD's business model for acquiring UMS?**
        - **How deep should the policy apply – to payloads?**
    - **Determination of the appropriate agency**
        - **OSD is consensus**
    - **Would provide industry motivation for "participation"**

Recommended Actions

- Better define "Interoperability" in the Joint Publications and Service Publications
- Find consensus on levels of interoperability within the standards; understand the business model for acquisition of unmanned systems
- Determine viability of specifying physical standards
- Identify method of assuring compliance of C2 standards
- Identify commonalities/differences in existing standards

Recommended Actions

- **Investigate implications of security issues related to C2 standards**

- **Validate software safety and other safety issues**

- **Document lessons learned from various UMS**

- **Generate guidance/policy to encourage standardization**

- **Determine if Government/industry is willing to incur the costs of supporting multiple standards**